VOLUNTARY CLEANUP
AND
REDEVELOPMENT ACT APPLICATION
FOR
SILVER SWAN MINE AREA
RICO, COLORADO

Submitted to:

**COLORADO DEPARTMENT OF
PUBLIC HEALTH AND ENVIRONMENT**

Submitted by:

**Atlantic Richfield Company
Rico Properties, L.L.C.**

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VOLUNTARY CLEANUP AND REDEVELOPMENT ACT APPLICATION

July 11, 1994 Draft

This application form is prepared by the Colorado Department of Public Health and Environment, to assist potential applicants in meeting the requirements outlined in the Voluntary Cleanup and Redevelopment Act (HB94-1299). Adherence to this application will insure that adequate information is submitted to allow the Department to evaluate the application and make a determination on the Voluntary Cleanup Plan or No Action Petition. All applications must include a filing fee of $2000. Department review time will be billed against this fee, with any remaining funds to be returned to the applicant.

GENERAL INFORMATION

The applicant should begin by providing the following general information:

Page

1-2 1) Name and address of owner
1-2 2) Contact person and phone number
1-1 3) Location of property
1-2 4) The type and source of contamination
1-2 5) If contamination will remain on property following implementation of your proposal, provide Global positioning system coordinates
1-2 6) State whether request is for approval of Voluntary Cleanup Plan (VCUP) or a petition of No Further Action Determination (NAD)
1-2 7) Current Land Use
1-2 8) Proposed Land Use

PROGRAM INCLUSION

This section is designed to determine whether the applicant meets the criteria for eligibility under the Act. Please answer yes (Y), no (N), or not sure (NS) to the questions below. If the answer to any of the questions is not sure (NS) please fill out the appropriate checklist questionnaire in Appendix 1 (these have not yet been developed at the time of the last draft). An answer "no" to question 1 or "yes" to questions 2-6 will result in a determination that the application is not eligible for the Voluntary Cleanup Program. The submission of misleading information will render any approval given by the Department void.

Page

1-3 1) Is the applicant the owner of the property for the submitted VCUP or NAD? IF yes, verify ownership.
Yes

1-3 2) Is the property submitted for the VCUP or NAD listed or proposed for listing on the National Priorities
No List of Superfund sites established under the federal act (CERCLA)

1-3 3) Is the property submitted for which the VCUP or NAD the subject of corrective action under orders or
No agreements issued pursuant to the provisions of Part 3 of Article 15 of this Title or the federal "Resources Conservation and Recovery Action of 1976", as amended? If yes, please list order number.

1-3 4) Is the property submitted for the VCUP or NAD subject to an order issued by or an agreement (including
No permits) with the Water Quality Control Division pursuant to Part 6 of Article 8 of this Title? If yes, please list order or permit number.

1-3 5) Is the property submitted for the VCUP or NAD a facility which has or should have a permit or interim
No status pursuant to Part 3 of Article 15 of this Title (RCRA Subtitle C) for treatment, storage, or disposal of hazardous waste? IF yes, please list permit number.

NOTE: Properties that do not have a permit or interim status but at which hazardous waste, as defined in the Colorado Hazardous Waste Act and implementing regulations, was treated, stored, or disposed of at any time after 1980 is considered by the Department to have required a permit or interim status. Disposal is defined as any discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment.

1-4 6) Is the property submitted for the VCUP or NAD subject to the provisions of Part 5 of Article 20 of Title
No 8 (Underground Storage Tank - State Oil Inspector), C.R.S. or of Article 18 of this Title (RCRA subtitle I).

VOLUNTARY CLEANUP APPLICATION

Any plan for voluntary cleanup (VCUP) or request for no action determination (NAD) must include the following information to be considered complete. Applicants need to supply enough information in sufficient detail for the Department to make a determination. If certain information is not applicable to the site, the applicant may provide evidence and explanations as to why specifically requested information is not applicable. It is most important that the applicant describe the rationale used in performing the site investigation (including selection of sampling locations and parameters), performing risk assessments, selecting cleanup levels, and any other decision making process included in the application.

The applicant should include a cross reference listing the page number(s) of the application which correspond to the following listed information requirements on the blank line to the left of the information description on this form (or by other equivalent means).

ENVIRONMENTAL ASSESSMENT

Page

2-1 1) Environmental assessments must be submitted by qualified professionals, who are defined as persons having education, training, and experience in preparing environmental studies and assessments. The applicant should submit documentation, in the form of a statement of qualifications or resume, that the environmental assessment has been prepared by a qualified environmental professional.

1-2 2) The applicant should provide the address (if applicable) and legal description of the site, and a map of appropriate scale identifying the location and size of the property.

2-2 3) The applicant should describe the operational history of the property in detail, including the most current use for the property. This description should include, but not be limited to:

2-15	(xii) underground or above ground piping;
2-15	(xiii) air emission control scrubber or refrigeration units;
2-15	(xiv) water cooling systems or refrigeration units;
2-15	(xv) sewer lines;
2-15	(xvi) french drain systems;
2-15	(xvii) water recovery sumps and building foundations;
2-15	(xviii) surface impoundments;
2-14	(xix) waste storage and/or disposal areas/pits, landfills etc.;
2-14	(xx) chemical or product storage areas;
2-14	(xxi) leach fields; and
2-14	(xxii) dry wells or waste disposal sumps.

2-5 5) If groundwater contamination exists, or if the release has the potential to impact groundwater, the applicant should provide the following information for areas within one-half mile radius of the site:

2-5 (i) the State Engineer's Office listing of all wells within the one-half mile radius of the site, together with a map to scale showing the locations of these wells;

2-6 (ii) documentation of due diligence in verifying the presence or absence of unregistered wells supplying ground water for domestic use in older residential neighborhoods, or in rural areas;

Not Applicable (iii) a statement about each well within the half-mile radius of the site, stating whether the well is used as a water-supply well, or a ground water monitoring well;

Not Applicable (iv) lithologic logs for all on-site wells;

Not Applicable (v) well construction diagrams for all on-site wells, showing screened interval, casing type and construction details (obtainable from the State Engineer's Office), including: gravel pack interval, bentonite seal thickness and cemented interval;

2-5 (vi) a description of the current and proposed uses of on-site groundwater in sufficient detail to evaluate human health and environmental risk pathways. In addition, the applicant will provide a discussion of any State and/or local laws that would restrict the use of on-site ground water.

2-16 7) The applicant should provide information concerning the nature and extent of any contamination and releases of hazardous substances or petroleum products which have occurred at the site, including by not limited to:

2-16 (i) identification of the nature and extent, both on-site and off-site, of contamination that has been released into soil, ground water and surface water at the property, and/or releases of substances from each of the areas identified in Section 25-16-308(b) above;

2-16 (ii) a determination of whether or not, those substances identified in paragraph (i) above, contain hazardous substances either through process knowledge, Material Safety Data Sheet information provided by a manufacturer, or through chemical analysis;

2-16 (iii) a statement defining the chemical nature, mobility and toxicity of the substances identified in paragraph (i) above, estimated volumes and concentrations of substances discharged at each area, discharge point, drain, or leakage point;

<u>Not Available</u> (iv) a map to scale showing the depth to ground water across the site;

<u>Not Available</u> (v) a map to scale showing the direction and rate of ground water movement across the site using a minimum of three (3) measuring points;

<u>None</u> (vi) a discussion of all hydraulic tests performed at the site to characterize the hydrogeologic properties of any aquifers on-site and in the area;

<u>2-16&2-19</u> (vii) all reports and/or correspondence which detail site soil, ground water and/or surface water conditions at the site, including original analytical laboratory reports for all samples and analyses;

Separate Reports Provided (viii) a discussion of how all environmental samples were collected, including rationale involved in sampling locations, parameters, and methodology, a description of sampling locations, sampling methodology and analytical methodology, and information on well construction details and lithologic logs. All sample analyses performed and presented as part of the environmental assessment should be appropriate and sufficient to fully characterize all constituents of all contamination which may have impacted soil, air, surface water and/or ground water on the property. The applicant should use EPA approved analytical methods when characterizing the soil, air, surface water and/or ground water.

<u>APPLICABLE STANDARDS/RISK DETERMINATION</u>

<u>3-1</u> 1) The applicant should provide a description of applicable promulgated state standards establishing acceptable concentrations of constituents (present at the site) in soils, surface water, or ground water.

<u>3-1</u> 2) The applicant should provide a description of the human and environmental exposure to contamination at the site based on the property's current use and any future use proposed by the property owner. This description shall include, but not be limited to the following:

<u>2-15,2-16</u> (i) a table or list, for site contaminants indicating:

<u>Not Applicable</u> (a) whether they are known to be carcinogenic (together with any relevant toxicity information for each carcinogenic contaminant available, including the slope factor for the contaminant) or whether they are non-carcinogenic (together with any relevant toxicity information on each contaminant, including reference doses if available);

<u>2-16</u> (b) which media (i.e., soil, sir surface water and ground water) are contaminated, and the estimated vertical and areal extent of contamination in each medium;

<u>2-16</u> (c) the maximum concentrations of each contaminant detected on-site in the area on-site where the contaminant was discharged to the environment, <u>and/or</u> where the <u>worst</u> effects of the discharge are believed to exist;

<u>3-1</u> (d) whether the contaminant has promulgated state standard, the promulgated standard and the medium (i.e., ground water, surface water, air or soil) the standard applies to;

<u>3-1</u> (ii) a description and list of potential human and/or environmental exposure pathways pertinent to the **Present** Use of the property;

3-1 (iii) a description and list of potential human and/or environmental exposure pathways pertinent to the **Future Use** of the property;

2-16 (iv) a list, and map defining all source areas, areas of contamination or contaminant discharge areas;

2-16 (v) a discussion of contaminant mobilities, including estimates of contaminants to be transported by wind, volatilization, or dissolution in water. For those contaminants that are determined to be mobile and have the potential to migrate and contaminate the underlying ground water resources, the applicant should also evaluate the leachability/mobility of the contaminants. This evaluation should consider, but not be limited to, the following: leachability/mobility of the contamination; health-based ground water standards for the contamination; geological characteristics of the vadose zone that should enhance or restrict contaminant migration to ground water, including but not limited to grain size, fractures and carbon content and depth to ground water. This evaluation and any supporting documentation should be included in the plant submitted to the Department.

3-4 3) The applicant should then provide, using the information contained in the application, a risk assessment in accordance with standard EPA policy, or calculation of appropriate cleanup levels, using CDHPE hazardous Materials and Waste Management Division's **"Interim Final Policy and Guidance On Risk Assessment For Corrective Action At RCRA Facilities"** (November 16, 1993). The Department will evaluate this analysis based on an acceptable excess cancer risk of 1×10^{-6} or hazard index <1.

VOLUNTARY CLEANUP PROPOSAL

The voluntary cleanup plan must address known or potential releases of contaminants considering the human health and environmental risks of those contaminants in both the present and future land use scenarios. The plan must demonstrate that wither all applicable state standards will be met, or for contaminants where no standard exists, that the risk level has been reduced to an acceptable level (excess cancer risk of 10^{-6}, or hazard index <1).

The remediation alternative selected should be described in sufficient detail to allow the Department to evaluate whether or not the applicant will be capable of remediating all contamination identified at the subject property within the specified 24 month time limit set down in 25-16-306(4)(a). This plan should, at a minimum, include the following information:

4-7 1) A detailed description of the remediation alternative, or alternatives selected, which will be used to remove, or stabilize contamination released into the environment, or threatened to be released into the environment.

follows
4-9 2) A map identifying areas to be remediated, the area where the remediation system will be located, if it differs from the contaminated areas, locations of confirmation samples, the locations of monitoring wells, areas where contaminated media will temporarily be stored/staged, and areas where contamination will not be remediated.

follows
4-9 3) Remediation system design diagrams showing how the system will be constructed in the field.

4-17 4) A remediation system operation and maintenance plan that describes, at a minimum, how the system will be operated to ensure that it functions as designed without interruptions and a sampling program that will be used to monitor its effectiveness in achieving the desired goal.

<u>4-20</u> 5) The plan should describe how the waste, or contaminated media will be managed prior to treatment, and/or disposal.

<u>4-20</u> 6) The plan should discuss whether or not a hazardous waste will be generated by its implementation (e.g., through the excavation of contamination, which may have been discharged prior to 1980, but which would become a hazardous waste upon being dug up or managed), and the volume of this material. The plan should also describe how such hazardous waste will managed in accordance with current state and federal hazardous waste regulations.

<u>Not Applicable</u> 7) If applicable, the plan should describe the sampling program that will be used to verify that treatment of the contaminated media has resulted in a non-hazardous waste.

<u>Not Applicable</u> 8) The plan should described the sampling program that will be used to verify the no contamination above the health-based cleanup standard has been allowed to remain in the environment, or at a location that could potentially threaten human health and the environment.

<u>4-18</u> 9) The plan should describe all sampling collection methods to be utilized along with the field and/or laboratory methods that will be used to analyze the samples.

<u>4-23</u> 10) The plan should include a schedule of implementation.

<u>4-22</u> 11) The plan should identify all permits (Federal, state and/or local including, if necessary, EPA Form 8700-12-Notification of Hazardous Waste Activity, required on the generation of hazardous waste) that will be needed before the plan can be implemented.

<u>4-21</u> 12) The plan should discuss the potential risks associated with the proposed cleanup alternatives, and the economic and technical feasibility of these alternatives.

<u>4-17</u> 13) The plan should describe the post-VCUP monitoring plan to be implemented in order to verify attainment of appropriate standards or risk levels as identified as cleanup targets.

____ 14) If not included in the risk assessment portion of the application, the plan should describe:

<u>2-16</u> (a) a final list of all site contaminants, along with the remaining concentrations;

<u>2-6</u> (b) a final list defining which media (i.e., soil, surface water and ground water) are contaminated, and the estimated vertical and areal extent of contamination to each medium;

<u>2-16</u> Figure 2-1 (c) a final list, and map defining all source areas, areas of contamination or contaminant discharge areas; and

<u>4-21</u> (d) a description of the mechanisms for insuring that use of the land is consistent with the plan.

Voluntary Cleanup and Redevelopment Act Application for Silver Swan Mine Site Rico, Colorado

1.0 GENERAL INFORMATION

1.1 Applicants

The property owner identified herein in cooperation with the Atlantic Richfield Company (collectively referred to as "Applicants") are submitting this application to the Colorado Department of Public Health and Environment (Department) in accordance with the requirements outlined in the Voluntary Cleanup and Redevelopment Act (HB94-1299) and the July 11, 1994 Draft Application Form.

The Applicants fully support the voluntary cleanup program as an effective mechanism to provide for the protection of human health and the environment and to foster both the redevelopment and reuse of mined lands occupied by the historic inactive Silver Swan mine facility ("Site") at Rico, Colorado (Figure 1-1). The Applicants are as follows:

1. Atlantic Richfield Company (ARCO), prior owner of certain property
2. Rico Properties, L.L.C., current property owner

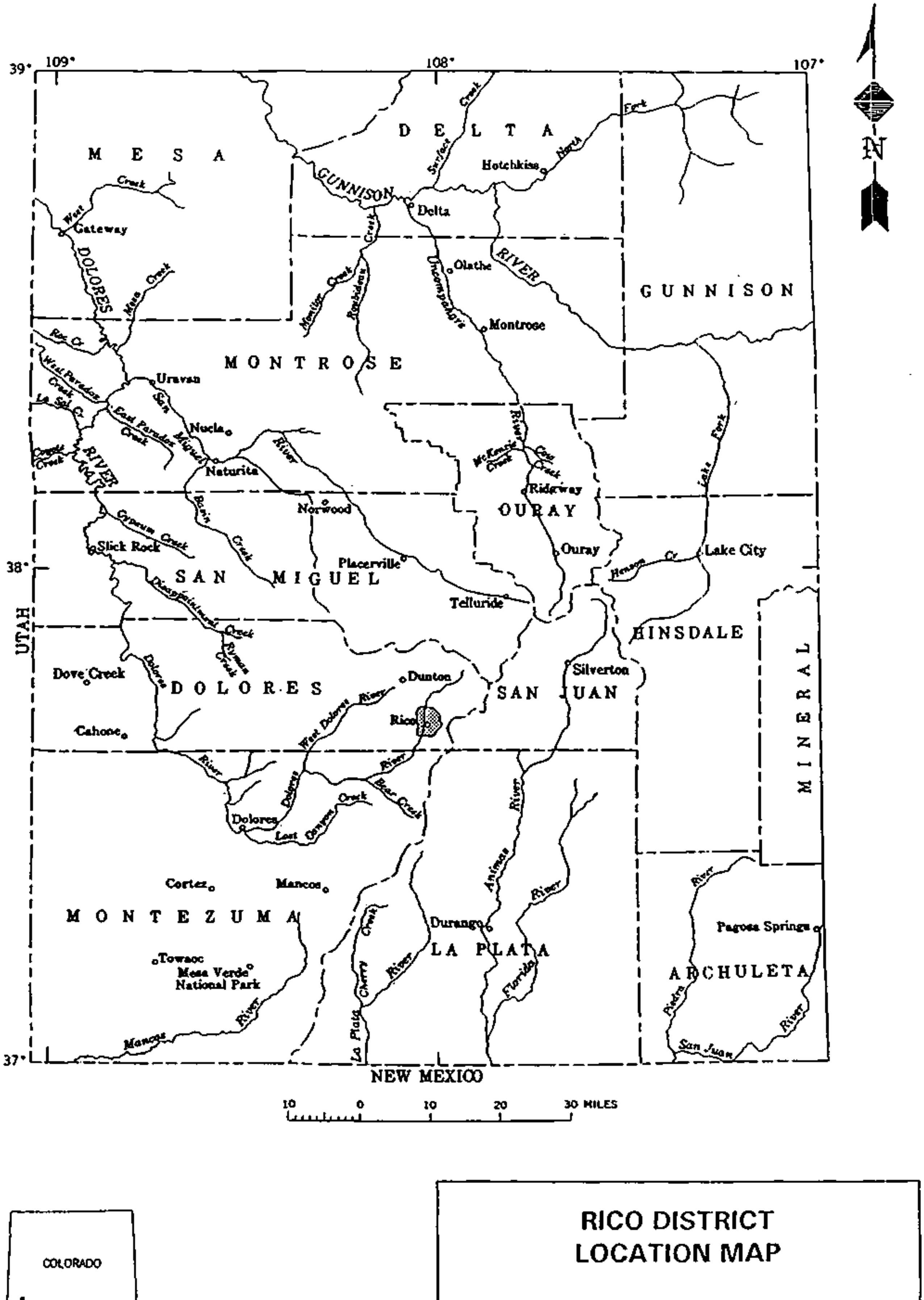
1.2 General Site Information

This section provides general site information, as specified in the application form.

1. Location and Size of Site

   a. General Site Location and Size.

   The site is located on the west side of Dolores River corridor in southwest portion of the Rico townsite. The Silver Swan is a historic inactive underground mine. The site area is approximately 4 acres and includes the rock-filled mine adit portal, main wasterock pile (2.3 acres), wetlands (1.5 acres), and a small wasterock pile (0.2 acres on the east side of the Dolores River).



RICO DISTRICT
LOCATION MAP

FIGURE 1-1

b. Land Description.

The Site is located in a portion of the S1/2 of the SE1/4 of the SE1/4 of Section 35, T40N, R11W, NMPM, Dolores County (Figure 1-2):

The Site comprises portions of the A.E. Arms Tract North, A.E. Arms Tract, F.G. Day Tract, A.E. Arms Tract South, and R.G.S. R.O.W. South (Figure 1-3).

2. Property Owner and Contact Person

a. A.E. Arms Tract North, A.E. Arms Tract, F.G. Day Tract, A.E. Arms Tract South, and R.G.S. R.O.W. South.
Book 266, Page 448, 451 and 452, Dolores County Clerk.

Rico Properties, L.L.C.
P.O. Box 220
17 Glasgow Avenue
Rico, CO 81332
Contact: Stan Foster, Manager (970) 967-5441

3. Type and Source of Contamination

Heavy metals derived from historic passive mine drainage and mineralized mine waste (predominantly iron, lead and zinc).

4. Site Coordinates

N15935, E18630 at Silver Swan adit based on Town of Rico survey coordinate system where N20000, E20000 is the point of intersection of Glasgow Avenue (Highway 145) and Mantz Street. Global positioning system coordinates are not available.

5. Statement of Request for Approval

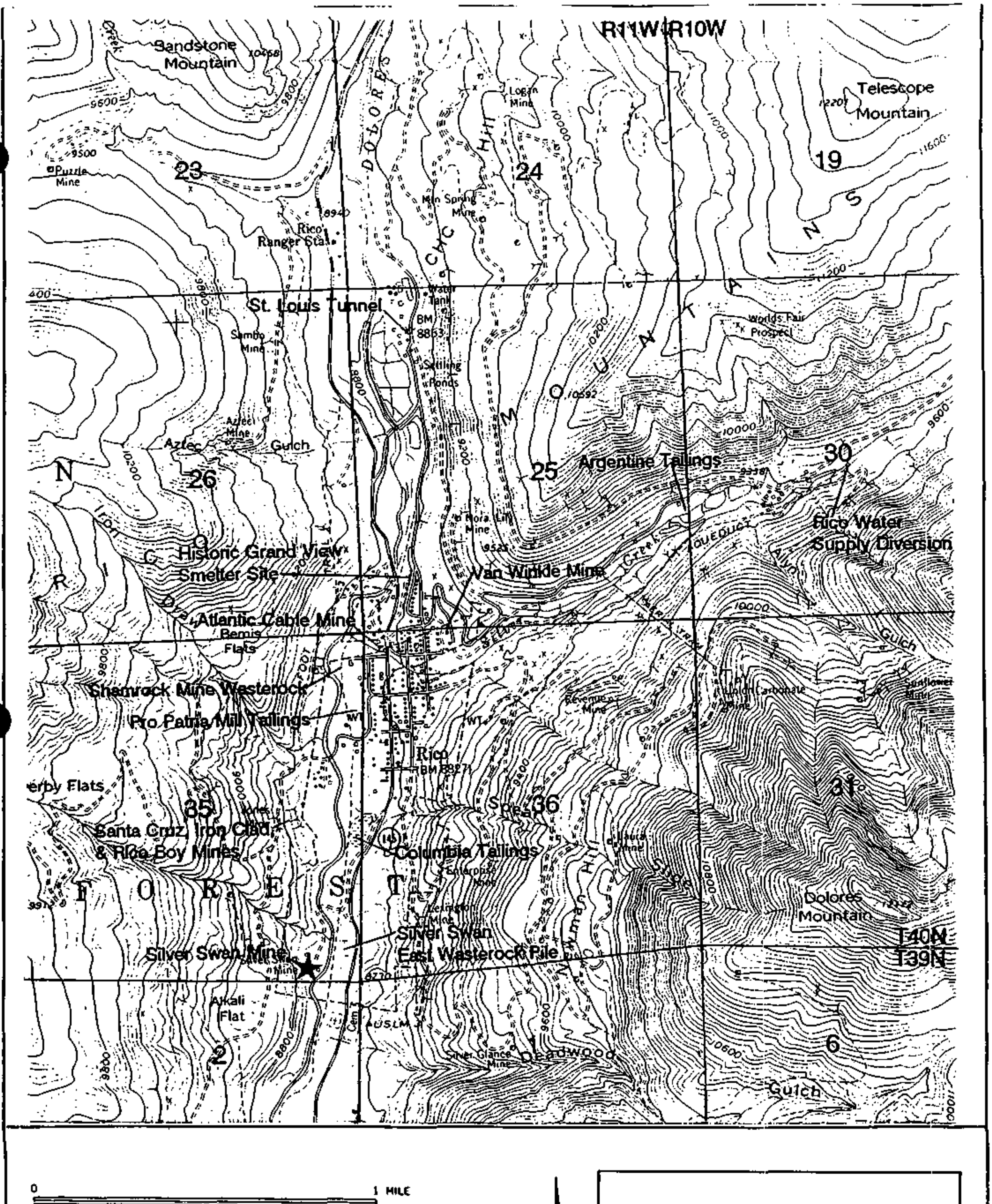
The Applicants request approval of Voluntary Cleanup Plan (VCUP).

6. Current Land Use

Undeveloped inactive mine site. See Rico area current land use map (Figure 1-4).

7. Proposed Land Use

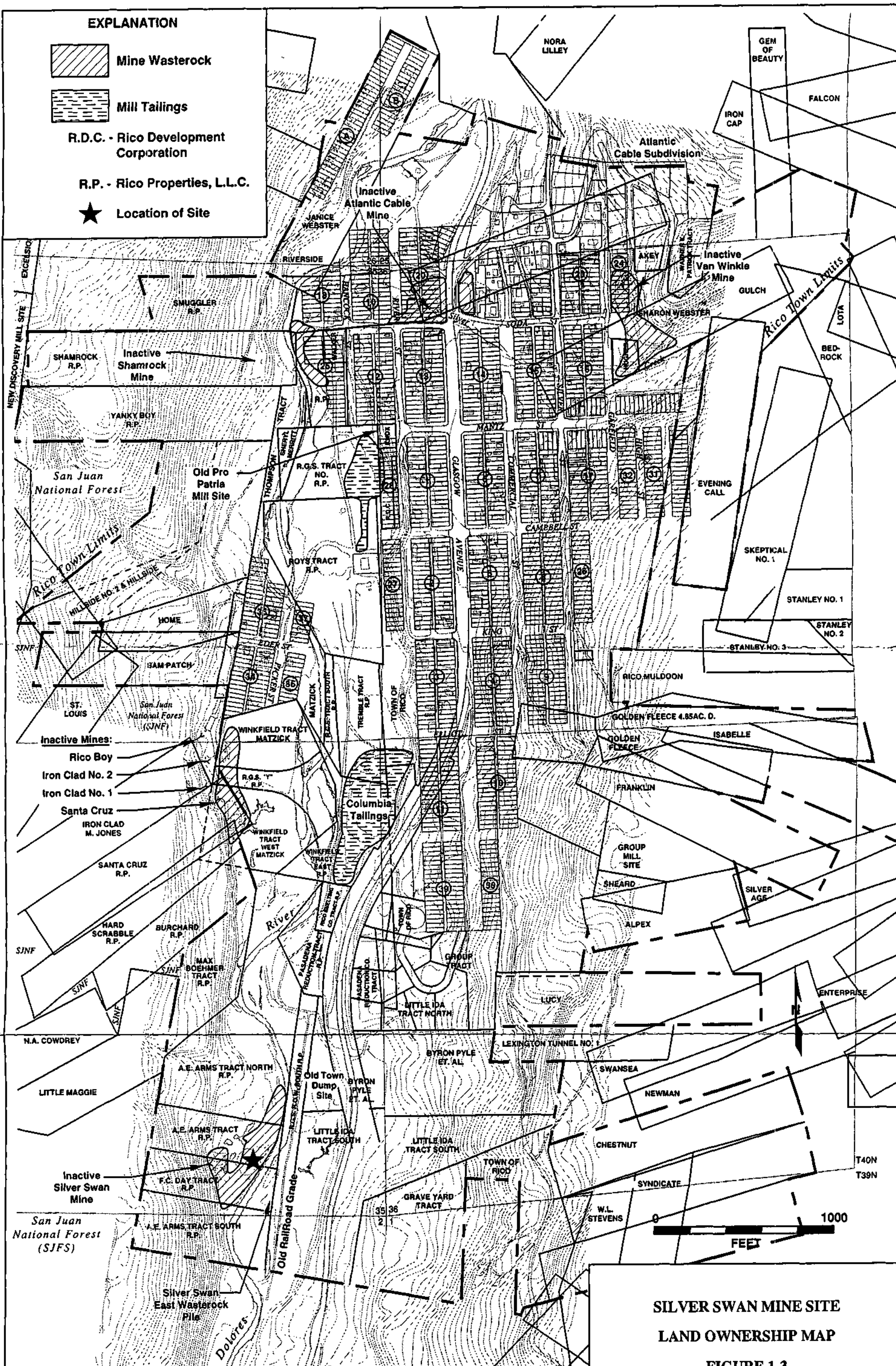
Continued undeveloped historic inactive mine site.



SILVER SWAN MINE
SITE LOCATION MAP

FIGURE 1-2

Section lines added.
Base Map: USGS Rico Quadrangle, Colorado, 7.5 Minute Series.



SILVER SWAN MINE SITE

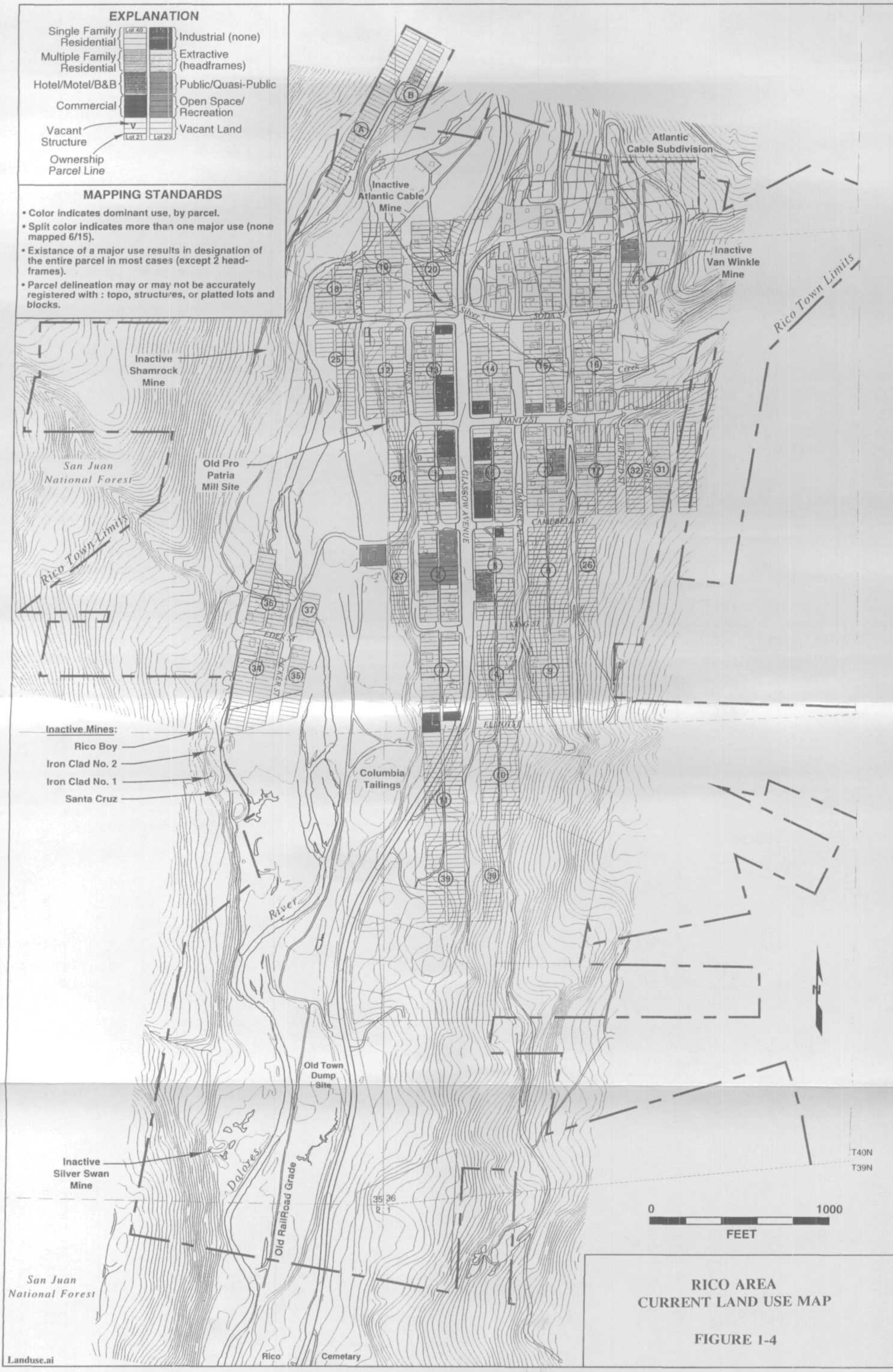
LAND OWNERSHIP MAP

FIGURE 1-3

Color Map(s)

The following pages contain color that does not appear in the scanned images.

To view the actual images, please contact the Superfund Records Center at (303) 312-6473.



RICO AREA
CURRENT LAND USE MAP

FIGURE 1-4

1.3 Program Inclusion Questionnaire

This section answers the questions listed in the application form as required to determine that the applicants meet the criteria for eligibility under the Act. An answer "yes" to question 1 and "no" to questions 2-6 indicate a determination that the application is eligible for the Voluntary Cleanup Program.

1. *"Is the applicant the owner of the property for the submitted VCUP or NAD? IF yes, verify ownership."*

   Yes. The owner applicant, Rico Properties, L.L.C., is the current owner of the properties for the submitted VCUP. Ownership is verified according to Book and Page number of applicable conveyance instruments on record with Dolores County Clerk (See Section 1.2).

2. *"Is the property submitted for the VCUP or NAD listed or proposed for listing on the National Priorities List of Superfund sites established under the federal act (CERCLA)."*

   No.

3. *"Is the property submitted for which the VCUP or NAD the subject of corrective action under orders or agreements issued pursuant to the provisions of Part 3 of Article 15 of this Title or the federal "Resources Conservation and Recovery Action of 1976", as amended? If yes, please list order number."*

   No.

4. *"Is the property submitted for the VCUP or NAD subject to an order issued by or an agreement (including permits) with the Water Quality Control Division pursuant to Part 6 of Article 8 of this Title? If yes, please list order or permit number."*

   No.

5. *"Is the property submitted for the VCUP or NAD a facility which has or should have a permit or interim status pursuant to Part 3 of Article 15 of this Title (RCRA Subtitle C) for treatment, storage, or disposal of hazardous waste? Yes, please list permit number."*

   No.

6. *"Is the property submitted for the VCUP or NAD subject to the provisions of Part 5 of Article 20 of Title 8 (Underground Storage Tank - State Oil Inspector), C.R.S. or of Article 18 of this Title (RCRA Subtitle I)?"*

No.

2.0 ENVIRONMENTAL ASSESSMENT

2.1 Introduction

Pursuant to the specific information requirements outlined in the Voluntary Cleanup and Redevelopment Act, the environmental assessment section and appended documents provide the following categories of information:

- Qualifications of professionals who prepared the environmental assessment, applicable standards/risk determination and voluntary cleanup plan sections of this application;
- Location/size, operational history and current use of the Site;
- Physical and ecological characteristics of the Site, including descriptions of site investigations and results and previously implemented remedial measures;
- Nature and extent of on-site and off-site contamination; and
- Brief explanation as to why certain specifically requested information is not applicable.

2.2 Qualification of Environmental Professionals

"Environmental assessments must be submitted by qualified professionals, who are defined as persons having education, training, and experience in preparing environmental studies and assessments. The applicant should submit documentation, in the form of a statement of qualifications or resume, that the environmental assessment has been prepared by a qualified environmental professional."

The environmental assessment, applicable standards/risk determination and voluntary cleanup plan have been prepared by a qualified team of environmental, risk assessment, and engineering professionals selected by Atlantic Richfield Company (ARCO). A corporate profile of the lead environmental engineering contractor, ESA Consultants Inc. (ESA), and the qualifications of the key personnel from ESA and other consulting firms who prepared the environmental assessment, risk determination and/or voluntary cleanup plan are included in Appendix A.

2.3 Location and Size of the Site

"The applicant should provide the address (if applicable) and legal description of the site and a map of appropriate scale identifying the location and size of the property."

The required information is provided under Section 1.2 General Site Information. The location and size of the Site are identified in Figures 1-2, 1-3 and 2-1. Figures 2-2a and 2-2b are photographs of the Site.

2.4 Operational History

"The applicant should describe the operational history of the property in detail, including the most current use of the property. This description should include, but not be limited to:

- *a description of all business/activities that occupy or occupied the site as far back as records/knowledge allows; and*
- *a brief description of all operations which may have resulted in the release of hazardous substances or petroleum products at the site, both past and present, including the dates activities occurred at the property, and dates during which the contaminants were released into the environment."*

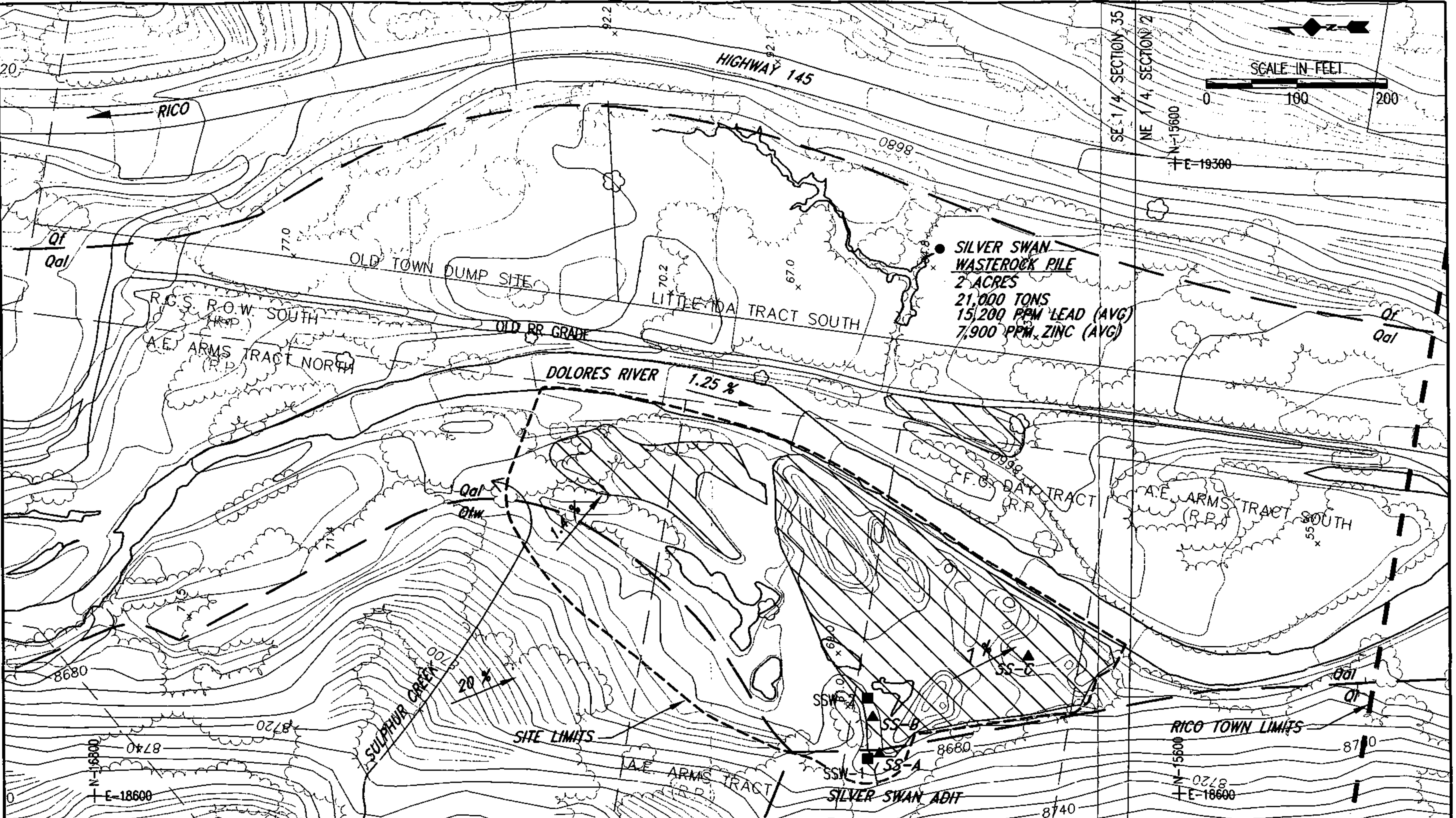
2.4.1 Introduction

There are a number of mines and associated surface disturbances located on the southwest side of the Rico district on the west side of the Dolores River (Figure 1-2). The Silver Swan mine is about a half a mile south of the Iron Clad group (Santa Cruz mine area). There are no reports in the literature of any ore processing facilities having been located at the Silver Swan mine or the other mines west of the river. The Silver Swan mine is currently discharging water and mine wasterock piles exist on both sides of the Dolores River (Figure 2-2a).

2.4.2 Period of Active Operation (1917-1972)

The first mention of the Silver Swan mine appears in 1917 with two cars of ore shipped during April of that year. The Silver Swan mine was acquired by Rico Mining and Reduction Company in 1926. These holdings were transferred to St. Louis Smelting and Refining Company in May 1927. St. Louis developed these holdings and ore from this mine was apparently shipped to custom mills in Bauer, Utah (CBM, 1926) from 1926 through 1929.

Several carloads of ore from the Silver Swan were shipped to Utah in 1947. From 1949 through 1953, Rico Argentine Mining Company (owner/operator) processed the ore at its Rico Argentine mill on Silver Creek. Mine production in 1951 was 15 tons per day (CBM, 1951).



LEGEND

10 % — SLOPE AND DIRECTION

WASTEROCK PILE

ADIT

GEOLOGIC UNITS CONTACT (APPROX.)

SS-A — WATER QUALITY SAMPLING LOCATION (SS=SILVER SWAN; A&B=ADIT DISCHARGE; C=SEEP)

SSW-1 — WETLANDS SEDIMENT SAMPLING LOCATION (SSW=SILVER SWAN WETLANDS)

SILVER SWAN MINE SITE
SITE FEATURES MAP

FIGURE 2-1

No records of any production after 1953 have been identified. Reported activity at the Silver Swan seemingly ended in 1972 with the conclusion of Rico Argentine's exploration and assessment work (CBM, 1972).

2.4.3 Period of Inactive Operations (1972-Present)

In 1981, Anaconda Minerals Company blocked access to the adit portal, a porous rockfill, and cleaned up the surface of the area as a part of a hazard abatement program. The rockfill was designed to allow mine drainage to continue.

2.4.4 Current Land Use

Applicant shall describe the *"current land uses, zoning, and zoning restrictions of all areas contiguous to the site"*.

The Site remains as an undeveloped inactive mine site on private land (Figure 1-3). Contiguous area land use includes the undeveloped Dolores corridor and San Juan National Forest land. The eastern portion of the Site lies inside the Town of Rico and is subject to zoning.

Appendix B provides a description of existing and future land use considerations for the Rico area. This information is important to the voluntary cleanup process at this Site because the Site is being considered as one of the elements of the Town of Rico's proposed Dolores River corridor plan. As such, it would be integrated into the Town's community-based master plan. See App B

2.4.5 Other Requested Operations Information

- A list of all *"site specific notifications made as a result of any management activities of hazardous substances conducted at the site"*.

  No such activities have been conducted by the Applicants at the Site.

- A list of *"notifications to county emergency response personnel for the storage of reportable quantities of hazardous substances"*.

  No such notifications have been made by the Applicants. No hazardous substances are stored at the Site.

- A list of *"notifications made to State and/or Federal agencies as a reporting spills and/or accidental releases"*.

  No such notifications have been made by the Applicants.

- A list of all *"known hazardous substances used at the site, with volume estimates"*.

  The Applicants are not aware of any known hazardous substances used at the Site.

- A list of all *"wastes generated by current activities conducted at the site, and manifests for shipment of hazardous wastes off-site"*.

  There are no current activities generating any wastes at the Site.

- A list of all *"permits obtained from State or Federal agencies required as a result of the activities conducted at the site"*.

  Due to the historical inactivity at the Site, no State or Federal permits have been required.

2.5 Physical and Ecological Characteristics of the Site

"The applicant shall describe the physical characteristics of the site...":

2.5.1 Climate

The climate at Rico is characterized as semi-arid with long, cold snowy winters and short, moderately warm and wet summers. Monthly and annual climatic data has been compiled by the Colorado Climate Center at Colorado State University for Rico station 57017 from 1893 through 1993. The annual mean temperature is 38.7°F. The warmest months are June, July and August with monthly mean temperatures of about 52, 57 and 56°F respectively. The highest monthly mean maximum and minimum temperatures also occur during these same months. The coldest months are December, January and February with respective monthly mean minimum temperatures of 6.9, 5, and 7.2°F. The growing season is relatively short because the annual frost-free period for soils ranges between 40 and 75 days (NRCS, 1995).

Mean annual precipitation is about 27 inches. Most of it occurs as snowfall in the fall, winter and spring which averages 173 inches per year. Average total monthly precipitation ranges between about 1.4 and 3 inches. Eight months average between 2 and 3 inches of precipitation and four months average between 1.4 and 2 inches. The driest month is June . The wettest months are July and August with rainfall averaging almost 3 inches each month. The driest fall month is November averaging about 1.9 inches.

2.5.2 Topography

The topographic characteristics of the Rico Mountains area are high relief, very steep to steep mountain sideslopes, and steep to moderate sloping tributary stream valleys, all of which abruptly descend upon the gently to moderately sloping and relatively narrow Dolores River valley (Figures 1-2 and 2-1). Many of the steep draws and gulches formed on the hillsides on both sides of the Dolores River and its Silver Creek tributary are snow avalanche chutes. Elevations in the Rico area generally range from over 12,000 feet at the crest of surrounding mountain peaks, such as Telescope Mountain (12,201) and Dolores Mountain (12,112) to 8,700± feet in the Dolores River valley at Rico. The intersection of Glasgow Avenue (Highway 145) and Mantz Street in the Town of Rico is at an elevation of about 8,800 feet.

The Silver Swan mine area is situated at the base of the steep Expectation Mountain east slope on the west side of the Dolores River valley (Figure 2-1). The valley elevation at the Silver Swan is about 8,660 feet and the crest elevation of the wasterock pile is about 8,680 feet. The topography of the mine area is depicted in Figure 2-1.

2.5.3 Surface Water Bodies

The Dolores River below the Town of Rico has a mean annual historic flow of 132 cfs with a typical seasonal flow range of between 20 and 600 cfs. Monthly flow data for the Dolores River for the period 1951 through 1993 is summarized in Table 2-1. Flood frequency analysis data and floodplain for 100-year and standard-project floods are provided in Appendix C1B. The annual high flows occur during snowmelt runoff in May and June. The annual low flow period occurs in November through March with January and February having the lowest average monthly flow of 19 and 18, respectively. The 100-year flood peak is estimated at about 2,700 cfs (D&M, 1981a). Dolores River water quality is described in Section 2.6.3.

2.5.4 Surface Water and Ground-Water Supplies

There is no use of surface water or ground water as sources of water supplies at the Site or in areas contiguous to the Site. Silver Creek is the source of water supply for the Town of Rico. The point of diversion for the water supply is located approximately 1.25 miles above the townsite. (Figure 2-3). Although the west Rico area is also served by the town's water supply system, at least three residences obtain water from Iron Gulch.

There are no known ground-water monitoring or supply wells within the one-half mile radius of the Site. Colorado Division of Water Resources records were searched for all registered wells in the east end of Dolores County. Most of the wells of record are located several miles west of Rico in the Dunton area in the West Dolores River Basin (Figure 1-1).

TABLE 2-1

Monthly Flow Data for Dolores River 1951-1993
USGS Gauging Station 0916500
(Flow in cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
AVG	19	18	29	123	458	566	171	81	62	42	28	21	132
MAX	38	34	72	242	1015	1288	646	255	224	133	58	43	239
YR	1958	1985	1972	1962	1958	1957	1957	1957	1982	1972	1972	1957	1957
MIN	8	8	11	43	99	71	37	31	17	15	12	12	40
YR	1990	1961	1964	1975	1977	1977	1959	1972	1956	1956	1956	1963	1977
COUNT	39	39	39	39	39	39	39	39	39	36	36	36	35

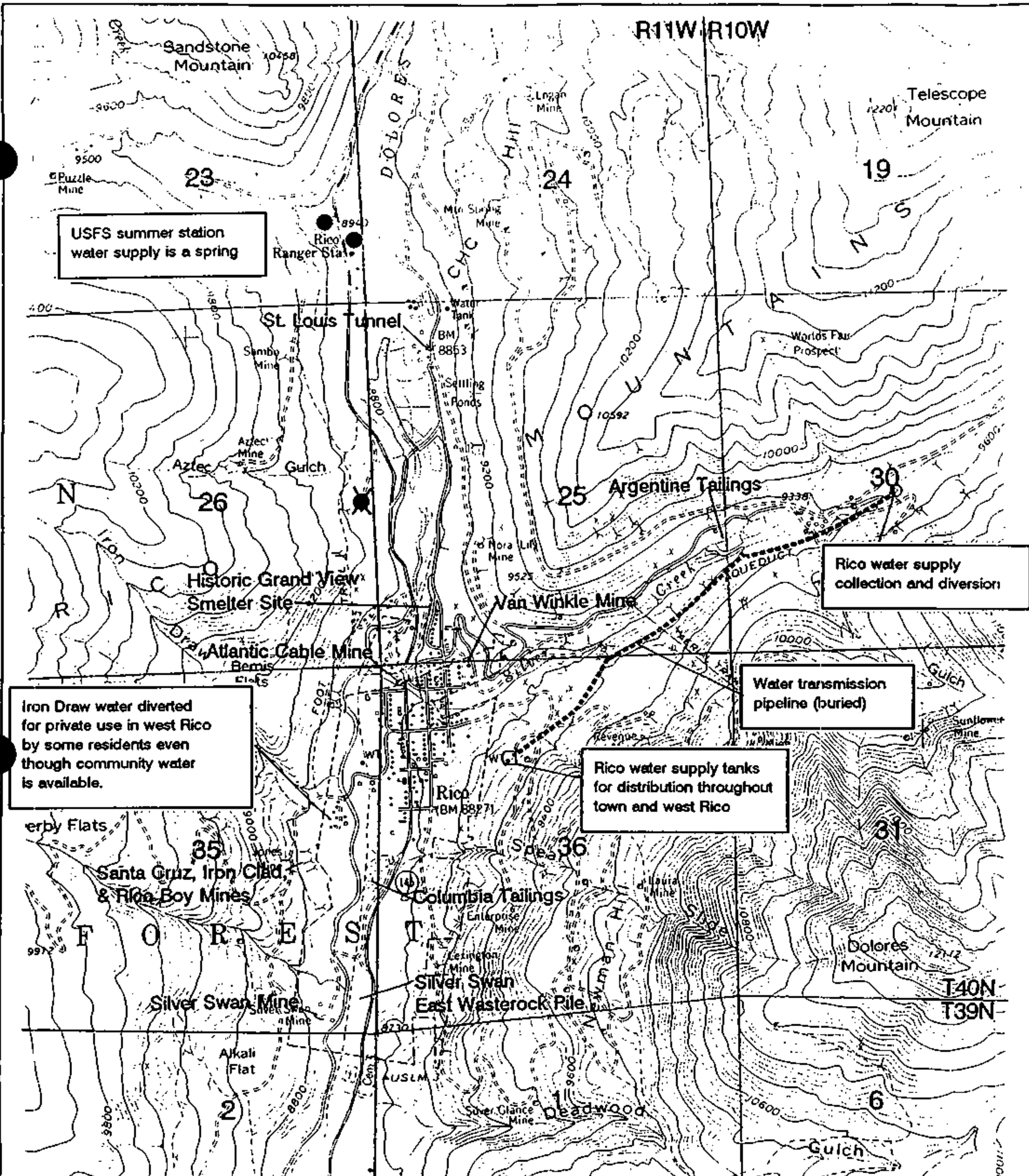
Color Photo(s)

The following pages contain color that does not appear in the scanned images.

To view the actual images, please contact the Superfund Records Center at (303) 312-6473.

Figure 2-2a. Silver Swan Site (southwest) September, 1995

Figure 2-2b. Silver Swan Site (south) September, 1995



EXPLANATION

- Permitted household use only supply well - upgradient of Rico Townsite
- Abandoned and plugged Colorado Department of Transportation supply well

No registered or unregistered domestic or irrigation supply wells, or monitoring wells exist within the half-mile radius of site.

Section lines added.
Base Map: USGS Rico Quadrangle, Colorado, 7.5 Minute Series.

COMMUNITY WATER SUPPLY AND GROUND-WATER SUPPLY WELLS

FIGURE 2-3

There are three registered supply wells in the Rico area. These are located above the Rico townsite on the west side of the Dolores River valley (Figure 2-3). Two of the wells supply water for domestic use and are located about 2 miles north of the Site. The third well is no longer used by the Colorado Department of Transportation and has been abandoned and plugged. There are no known unregistered water wells within the townsite or along the Dolores River.

2.5.5 Vegetation Communities/Wildlife Habitats/Sensitive Species

An ecological investigation of the Rico area was conducted by Cedar Creek Associates in June 1995 to characterize major vegetation communities/wildlife habitats, identify general impacts from mining-related and other land use disturbances, and assess the potential occurrence of sensitive species. The area of investigation included the Dolores River valley between Horse Creek and the Rico Cemetery. The results of the investigation are provided in a report prepared by Cedar Creek (1995a), which has been submitted with this application under separate cover. Ecological characterization information included in the report concerning the Site and contiguous areas is summarized below. Figure 2-4 is a vegetation communities/wildlife habitats/land use map.

2.5.5.1 Vegetation Communities/Wildlife Habitat

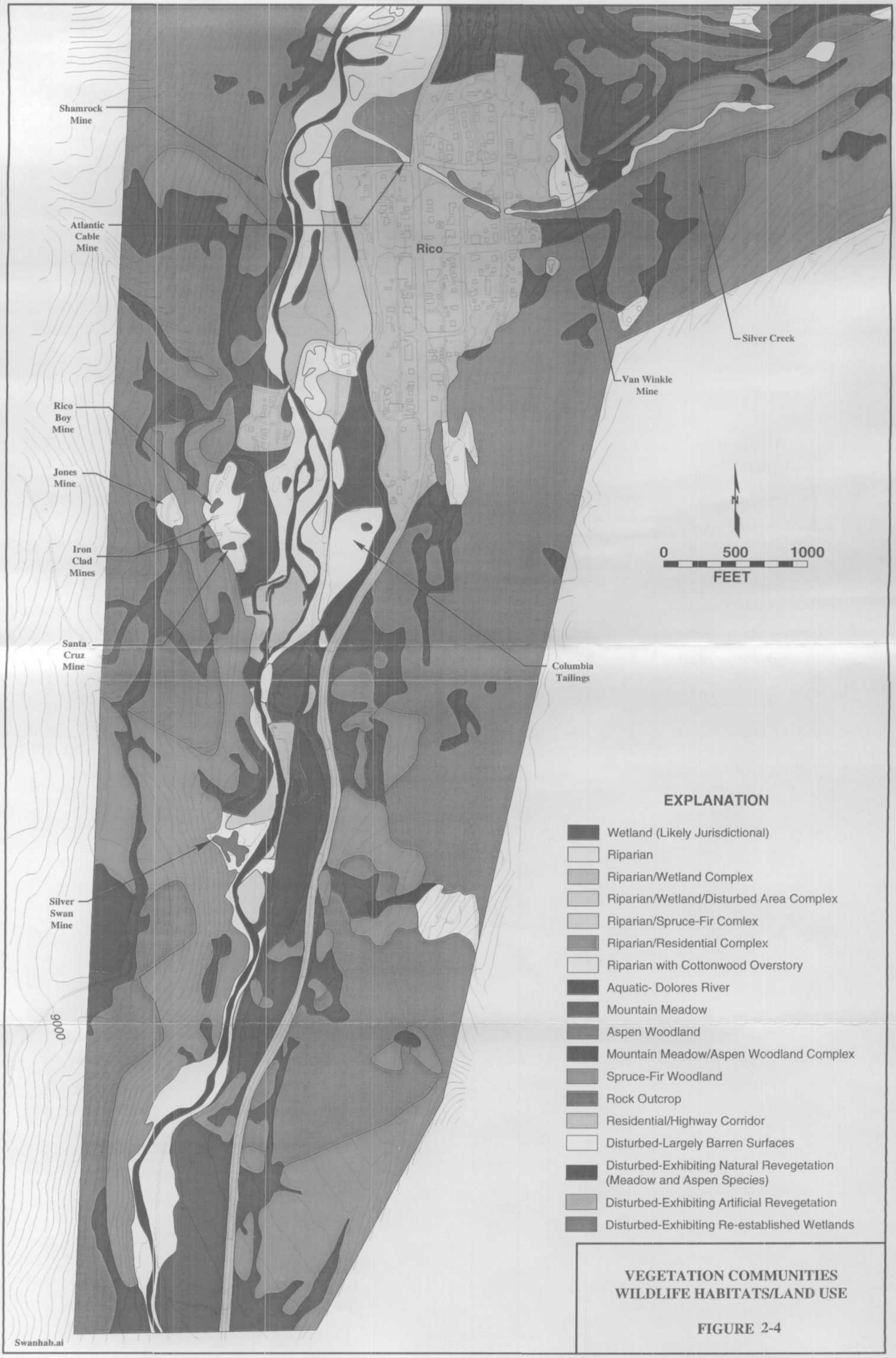
Wasterock material is largely barren and devoid of vegetation, but includes small areas of disturbance exhibiting natural revegetation. The predominant vegetation/wildlife habitats contiguous to the Site are in good condition, stable and used by wildlife at expected levels. The predominant vegetation communities contiguous to the Site are:

- Spruce-fir woodland on the mountain slopes immediately above the Site; and
- Wetland/riparian in the Dolores River corridor.

The spruce-fir community is the second most extensive vegetation type in the Rico area. It is located primarily above 8,500 feet elevation. The structural diversity and condition of the spruce-fir woodland is excellent and stable. Overall, the apparent biodiversity of this community appears to be very good with use by wildlife, especially big game species, at expected levels.

The natural wetlands in the riparian corridor are largely related to natural stream channel fluctuations of the Dolores River and the activity of beavers. Side channels of the Dolores River and/or tributaries are occasionally dammed in a typical stair-stepped manner.

The structural diversity of the natural wetland community is fair to good owing to a dense herbaceous stratum interspersed with some pools and ponds and an intermittent, and often thick, shrub stratum typically dominated by willows. Structural diversity can be rated as excellent



VEGETATION COMMUNITIES WILDLIFE HABITATS/LAND USE

FIGURE 2-4

where an overstory of cottonwood, spruce, or alder is present. The wetland community's utility as wildlife habitat is superior to all other communities with the possible exception of the riparian type. Wetlands provide an excellent source of both forage and cover to a wide variety of species, from big game to furbearers to avifauna. Furthermore, wetlands typically provide the only source of free water available for wildlife consumption during drier portions of the year. The natural wetlands condition and trend are rated very good and stable, respectively. A more detailed description of the wetland at the Site is provided in Section 2.5.6.

The riparian community/habitat is the fourth least extensive type within the Rico area and typically exists as one of two forms. The primary type occurs along the majority of the Dolores River corridor exhibiting a predominance of willows and young cottonwoods and alders. The second form consists of the first type with an overstory of mature or nearly mature narrow-leaf cottonwood. Furthermore, the riparian type forms complexes of inseparable units with several other communities including: wetlands, wetlands and old disturbance areas, and spruce-fir woodland (Figure 2-4).

The structural diversity of the riparian community is good to excellent. The riparian community's utility as wildlife habitat is superior to all other communities with the possible exception of the wetland type. Like the wetland type, the riparian community provides water and is an excellent source of both forage and cover to a wide variety of species, from big game to furbearers to avifauna. Furthermore, the physiognomic and topographic nature of the community enhances its utility as a travel corridor for migratory big game animals such as elk and mule deer.

2.5.5.2 Threatened/Endangered Species and Critical Habitats.

There are no known or suspected occurrences of listed threatened or endangered species or critical habitats in the Rico area (Cedar Creek, 1995a).

2.5.6 Silver Swan Site Wetland

The information provided in this section is based on the wetland investigation conducted by Pintail Systems and Schafer Associates (PSI and SA, 1995; report provided with application under separate cover).

2.5.6.1 Hydrology

The Silver Swan adit discharges from the hillside into the southern portion of a low-gradient grassy meadow/wetland area that totals about 1.5 acres. The portion of the wetland formed by the adit drainage is a series of ponds bordered by willows that have developed on top of lower areas of a series of wasterock piles. In June 1995, the adit discharge was about 50 gpm, which is equal to its average discharge rate as described in Section 2.6.2. In October 1995, the adit discharge had decreased to about 20 gpm.

The wetland formed by the adit drainage has developed on top of a wasterock pile and the water infiltrates into the pile before reaching the Dolores River. Less diverse vegetation in this meadow/wetlands has an obvious effect on the discharge hydrology. A more extensive vegetation cover would stabilize and distribute flow from the adit and upland slopes. Erosion within the stream channel is apparent and flow control from vegetation is minimal.

The northwestern portion of the meadow/wetland is a grassy area that receives drainage from one of two small streams that flow from the hillside over the Sulphur Creek alluvial fan. The stream draining into the meadow/wetland initially flows through an aspen/conifer glen in a sell-developed channel. The channel disappears as the water flows into the grassy area. In October 1995, this stream had a flowrate of about 28 gpm before it entered the grassy area. The second stream on the alluvial fan is less than 50 feet to the north of the first stream. It has a well-developed channel that flows into the northernmost part of the grassy wetland complex on the north side of an apparent drainage divide. The channel drains away from the wasterock and enters the Dolores River to the north. This drainage was flowing in June 1995, but was dry during the October 1995 sampling visit.

The meadow/wetland is affected by seasonal variations of adit discharge, snow melt and precipitation. In June 1995 the watertable in the grassy area was just at or near ground level. In October 1995, the watertable was encountered at a depth of about 3 feet below the surface in an excavated trench. The soil in the grassy area consists of about 1.5 feet of typical wetland organic substrate underlain by alluvial sand and gravel. Flow from grassy meadow/wetland joins the adit discharge/pond complex at the northwest end of the series of wasterock piles. The combined flow discharges to the Dolores River through a channel just north of the wasterock piles. In October 1995, all of the combined drainage disappeared into the alluvium in the drainage channel about 50 feet upstream of its confluence with the river.

2.5.6.2 Site Ecology and Biology

The Silver Swan area wetland is a meadow/wetland complex established on an alluvial terrace above the Dolores River. The Silver Swan area receives drainage from the mine adit, upslope surface run-off and precipitation into less than 1.5 acres of a poorly established meadow/wetland drainage.

Natural wetlands at the Site were field evaluated for dominant plant communities. The Silver Swan meadow/wetland area has few emergent soft-stemmed aquatic plants. The major community identification for the Silver Swan area would be graminoid dominant meadow/wetland with woody species emergent around the borders of the wetland. This is an area that could under the right time and conditions develop into a more productive wetland area but would be defined as poorly productive at the present time. Species diversity suggests that only simple remediation mechanisms (precipitation) are available for metal removal. The wetland area adjacent to the Silver Swan adit receives no other continuous source of surface water. Species identified during the field survey include sedges (Carex), grasses (Poa) and willow

(Salix). The opposite site of the Dolores River is colonized by a more diverse community of sedges, rushes, willow and graminoid species grading up to several woody-stemmed shrubs including Caprifoliaceae spp, Artemisia, Saxifraga and Compositae.

2.5.6.3 Wetland Sediment Geochemistry

Composite grab samples of sediment were collected at two locations about 20 and 70 feet downstream from the Silver Swan adit. The sample nearest the adit was mainly orange iron hydroxide floc. The second sample was black muck collected from among pieces of wasterock in the wetland. Total concentrations of iron, manganese, and zinc in the sediment samples are given in Table 2-2. The sediment sample nearest the adit contains over 25 percent iron. Based on the sediment color, this iron is in the form of hydroxide floc. Manganese concentrations in both sediment samples, at about 3 mg/kg, are low compared with typical oxidizing soils and sediments. On a worldwide basis, manganese in soils varies from about 10 to 9,000 mg/kg, and the maximum in the frequency distribution is between 200 and 800 mg/kg (Kabata-Pendias and Pendias, 1984). The relatively low manganese concentration in some of the sediments is probably due to Eh conditions (Table 2-3) that are somewhat reducing because manganese is typically most soluble under reducing conditions. The zinc concentration in the wetland sediment, at 7 mg/kg, is the highest measured in the Rico area wetland studies, but is still low by comparison with average soil or stream sediment zinc values. The average concentration of zinc in soils in the U.S. is 50 mg/kg in limestone terrain, and 75 mg/kg in volcanic terrain (Kabata-Pendias and Pendias, 1984). The higher concentration of zinc in the lower redox wetland sediment suggests that small amounts of zinc sulfide could be precipitating in the sediment as the drainage seeps through the wetland/wasterock environment. Thus, the reducing sediments may be removing dissolved zinc from any drainage passing through them.

Table 2-2
Silver Swan Wetland Sediment Analysis - Total Metals

Sample Site Description	Total Fe, pct	Total Mn, mg/kg	Total Zn, mg/kg	Distance from adit
#1 Silver Swan adit sediments	25.3	3.3	2.5	20 ft
#2 Silver Swan wetland pond	10.4	2.6	7.0	70 ft

Table 2-3
Silver Swan Wetland Sediment pH & Redox Potential

Sample Site Description	pH	Eh, mV	Distance from Adit
#1 Silver Swan adit sediments	6.3	70	20 ft
#2 Silver Swan wetland pond	6.3	-80	70 ft

2.5.6.4 Wetland Microbiology

Analysis of the Silver Swan sediments for total heterotrophic and sulfate reducing bacteria is shown in Table 2-4. Heterotrophic bacteria are single-celled microorganisms that derive all of their nutritional needs from organic substances.

Table 2-4
Wetland Sediment Microbiology

Sample Location ID	Sample Date	total hetero-trophs, CFU	sulfate-reducing bacteria, CFU's	HET/-SRB ratio	distance from Silver Swan Adit	Eh, mV
#7 Silver Swan adit	1 Jun 95	$3.5x10^5$	$2.0x10^2$	175:1	20	70
#8 SS wetland	1 June 95	$5.0x10^4$	$2.6x10^4$	2:1	70	-80

The results indicate that the sediments from the Silver Swan site contain diverse species of heterotrophic and sulfate-reducing bacteria (SRB). Heterotrophs can live both in the presence and absence of oxygen. Some species of these bacteria can aid in precipitating metals as hydroxide species by raising the pH and Eh in their microenvironments. SRB require anoxic conditions. They produce hydrogen sulfide, which can react with dissolved metals to form metal sulfides that precipitate, removing the metals from the water. Thus, both types of bacteria can remove metals form water passing through the sediments.

As shown in the tables, the heterotroph/SRB ratios correspond to the Eh of the sediment, with the lowest ratios found in the sediments with the lowest Eh values, indicating that each type of bacteria is most prevalent in its preferred environment. In the previous section on sediment geochemistry, the higher zinc concentration in the lower redox sediment indicated that zinc sulfides could be precipitating. The presence of significant numbers of SRB in the more reducing sediment provides additional indirect evidence that zinc sulfides may be precipitating there.

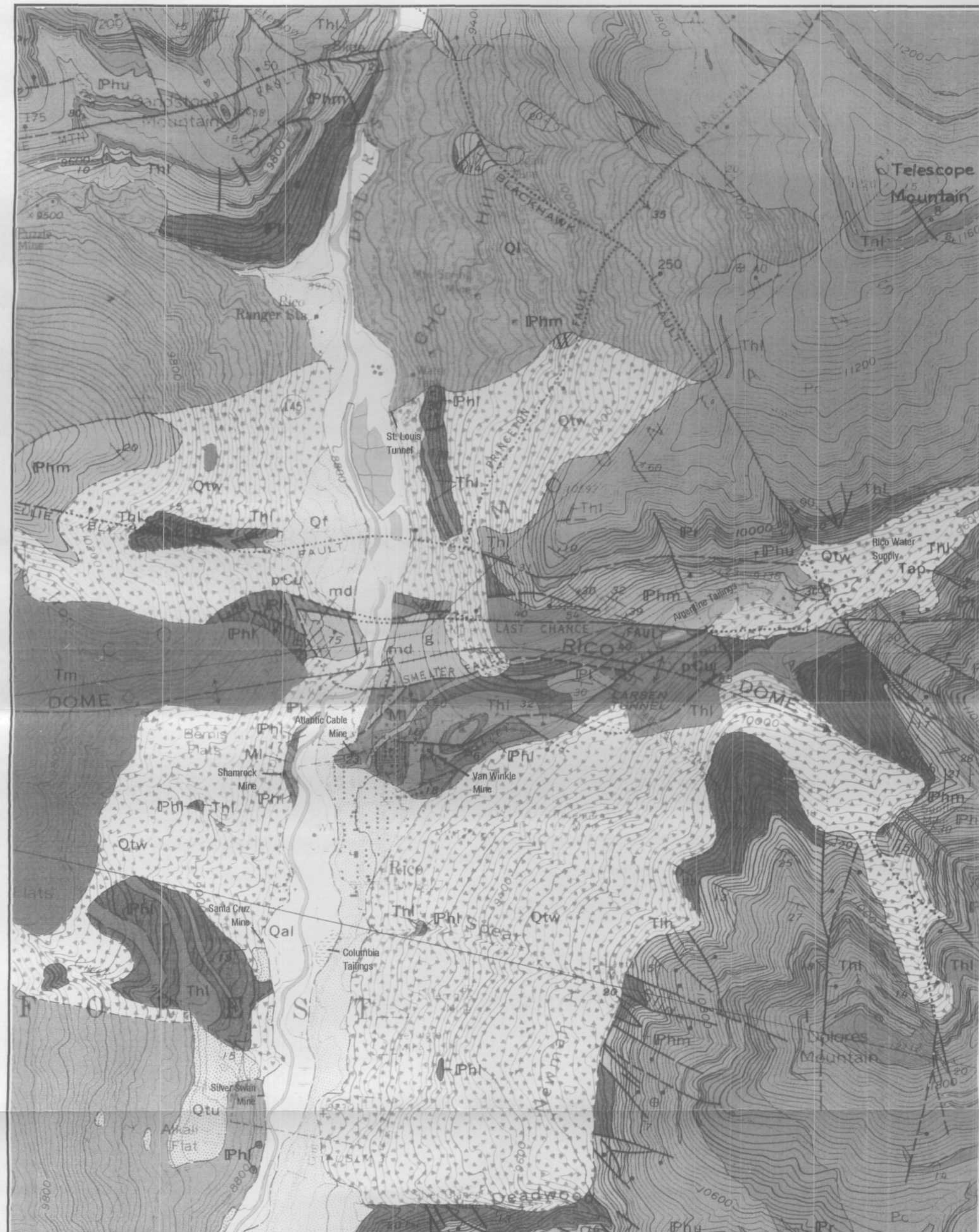
2.5.7 Geology

A geologic map and detailed descriptions of the geology and ore deposits of the Rico district are presented in U.S. Geological Survey Professional Paper 723 (McKnight, 1974). A geologic map of the Rico quadrangle has been published by the U.S. Geological Survey (Pratt, McKnight and DeHon, 1969). Figure 2-5 is a portion of the geologic quadrangle map with an explanation of the map units and symbols. The surficial geology of the Site area, based on the geologic quadrangle map and field observations, is depicted in Figure 2-1.

The dominant structure in the district is the faulted Rico dome (Figure 2-5). The major faults in the district are east-west trending normal faults. Many of the faults in the district in the district have been extensively mineralized, especially the Blackhawk fault. The Blackhawk fault cuts northwest to southeast diagonally across the other faults and the Silver Creek valley east of Rico where the mineralized fault zone has been extensively mined.

Bedrock in the Rico district comprises a wide variety of consolidated sedimentary strata ranging in age from Precambrian to Permian and Tertiary age igneous rocks that intrude sedimentary strata. In general, the older rocks are exposed in the Dolores River and Silver Creek valleys. Surficial deposits include alluvium (stream deposits), talus (rock debris) and slope wash (soil and rock debris), landslide deposits, and calcareous tufa (calcium carbonate deposits) (McKnight, 1974).

The Hermosa Formation is the most widely distributed formation in the mining district and comprises arkoses, sandtones, shales, conglomerates, and interbedded limestones. The Hermosa has been of great economic interest because most of the ore deposits in the district occur in it, particularly in the limestones (McKnight, 1974). In addition, it is of considerable environmental importance because the abundance of limestone, limy shale and limy sandstone units neutralize the acid-generating potential of sulfide ores, particularly pyrite. This natural neutralization of mineral acidity throughout the Rico district results in reduced potential concentrations of iron, cadmium, copper, lead, zinc, and other metals present in drainage to surface water bodies such as the Dolores River, Silver Creek and other tributary streams in the district.



Source: Pratt, Walden P., Edwin T. McKnight and René A. DeHon. 1969. Geologic Map of the Rico Quadrangle, Dolores and Montezuma Counties, Colorado. USGS Geologic Quadrangle Map GQ-797.

GEOLOGIC MAP OF A PORTION OF THE RICO QUADRANGLE

FIGURE 2-5

GEOLOGIC MAP EXPLANATION

Geologic Age	Map Symbol	Map Unit Description
Holocene	Qal	Alluvium. Coarse stream deposits (sand, gravel and boulders) confined to the Dolores River valley flood plain. The flood plain is narrowed by encroachment of torrential fan debris at the mouths of large tributary streams.
	Qf	Torrential fans. Cone-shaped deposits of coarse alluvium formed at the mouths of such tributary streams as Horse Creek, Aztec Gulch, Silver Creek, and Deadwood Gulch.
	Qtw	Talus and slope wash. Shown principally where bedrock relations are significantly obscured. Mantle of extensive soil and coarse rock debris that has accumulated on the lower slopes of mountains at Rico. The debris has washed or fallen down from higher slopes.
	Ql	Landslide deposits. Individual blocks of rock and/or talus and slope wash deposits that have broken loose and moved en masse down mountain slopes. The extensive landslide material underlying CHC Hill is several hundred feet thick and had to be traversed by most of the mines on this hill. No such landslide deposits exist in the Rico townsite area.
	Qtu	Calcareous tufa. Patches of calcium carbonate deposited from solution of water from an unidentified spring, which cap the slopes of the landslide and wash debris in the Alkali Flat area above the Silver Swan mine on the west side of the Dolores River south of Sulphur Creek.
Lower Tertiary	Tm	Augite monzonite. Medium-gray instrusive stock west of Rico composed of andesine crystals and interstitial potassic feldspar, hornblende, or augite and biotite, minor quartz, and accessory apatite, sphene, and magnetite.
	Tlh	Hornblende lamprophyre. Dark-gray fine-grained rock composed of crystals of hornblende, quartz, agate and olivine in a groundmass of plagioclase, hornblende, agate, and minor amounts of biotite, magnetite, and alternation products. Forms dike in middle member of Hermosa Formation (PPhm) east of Laura mine on Newman Hill.
	Tap	Alaskite porphyry, conspicuous rounded crystals of quartz and, locally, potassic feldspar, in pale-gray fine-grained groundmass of potassic feldspar and subordinate quartz. Forms small dikes, 10-15 feet wide, in lower member of Hermosa Formation (PPhl) in Aztec Gulch and in upper member of Hermosa Formation (PPhu) south of Silver Creek.
	Thl	Hornblende latite porphyry. Abundant white plagioclase crystals in altered groundmass which ranges from light to dark gray, greenish gray, or brownish gray, depending on abundance of chlorite and iron oxides as alteration products. Forms sills and small laccoliths a few feet to several hundred feet thick and dikes a few feet to several tens of feet wide, throughout the Rico Mountains.
Lower Permian	Pc	**Cutler Formation**: Interbedded siltstone and arkose. Siltstone is shaly, poorly sorted, and locally micaceous and (or) arkosic; generally reddish brown; includes minor fine-grained sandstone beds and nodular limestones. Arkose is generally coarse grained, locally conglomeratic, grading into arkosic conglomerate, and commonly crossbedded; generally purplish brown or banded purplish brown and grayish pink; conglomeratic beds pinkish gray or greenish gray. Commonly bleached to gray near large intrusions or major faults. Generally crops out as rounded ledges (arkose) alternating with undercuts or slopes (siltstone). About 2,100 feet thick where measured in northeast part of quadrangle.

Contact, showing dip

Long dashed where approximately located; short dashed where indefinite or inferred; dotted where concealed

Fault, showing dip

Long dashed where approximately located; short dashed where inferred; dotted where concealed; queried where existence is uncertain. Bar and ball on downthrown side. Vertical displacement, in feet, shown where measured or calculated. Faults in landslide area of CHC Hill projected from underground workings

Concealed inferred fault

Approximate crestline of elongated dome

Doubtful syncline

Strike and dip of beds — Strike of vertical beds — Horizontal beds — Strike and dip of foliation

Geologic Age	Map Symbol	Map Unit Description
Middle Pennsylvanian	Ppr	**Rico Formation**: Predominantly sandstone and arkose, in part conglomeratic, and subordinate shale and shaly limestone; sandy beds greenish gray, pinkish gray, purplish gray, or reddish brown; shaly beds commonly reddish gray or maroon, some greenish gray; limestones mostly gray or green, thin, and gnarly. Overall outcrop massive because of prevalence of thick sandstones and arkoses, in contrast to Cutler Formation. Marine fossils present in some limestones and limy sandstones. Top is thick massive sandstone. Base is a 10- to 25-foot-thick unit of dark-greenish-gray limy or sandy shale that overlies uppermost bed of Hermosa Formation. About 260-325 feet thick.
		Hermosa Formation
	PPhu	Upper member: Arkose, sandstone, some shale, some conglomerate (in upper half only), and minor thin beds of limestone, some of which are fossiliferous; uppermost bed is a 1-foot-thick bed of brownish-gray shaly or sandy limestone; brownish red or purplish gray, especially in upper part, and greenish gray, especially in lower part. About 720-830 feet thick.
	PPhm	Middle member: approximately one-half arkosic sandstone, one-third limestone, one-sixth shale. Distinctive feature of member is limestone; it is medium to dark gray, massively bedded, fine grained, fossiliferous, and mostly in units 10-40 feet thick, which are separated by greenish-gray, dark-gray, or locally brownish-red sandstones and shales. About 600-650 feet thick in Sandstone Mountain and Silver Creek, thinning to about 280 feet in Newman Hill, where massive limestones constitute about two-thirds of member.
	PPhl	Lower member: greenish-gray buff-weathering micaceous sandstone, siltstone, and arkose, locally conglomeratic, black and gray shale, and minor dark-gray limestone or dolomite; sandstone and arkose massively bedded or crossbedded, siltstone and shale thin bedded and slabby. Incompletely exposed; at least 880 feet thick.
	PPl	**Quartzite of Larsen tunnel area**: Coarse-grained quartzite containing quartz grains as much as 1-inch across in finer grained quartzose matrix; gray to brown, locally reddish gray; upper part interbedded with light-gray siltstone or shale; lower part massively bedded. Crops out near Larsen tunnel (one-half mile east of Rico along Silver Creek); narrow band through Rico is projected from underground workings and drill holes. About 80 feet thick, decreasing to 0 locally on west bank of Dolores River at Rico; basal contact not exposed.
Lower Mississippian	Ml	**Leadville Limestone**: White to gray crystallinelimestone and dolomite containing contact-metamorphic silicates and, locally, minor light-gray chert. Maximum exposed thickness 20 feet. Underlain in subsurface by Ouray Limestone of Late Devonian age; total aggregate thickness of both formations 120 to 170 feet.
Precambrian	p€u	**Uncompahgre Quartzite**: Pale-gray well-indurated quartzite, commonly stained red, containing quartz grains and pebbles; bedding generally obscure; pyritized chlorite schist layers and a light-gray dolomite bed present locally. Thickness unknown, but possibly greater than 1,000 feet.
	md	**Metadiorite**: Dark-gray coarse- to fine-grained unfoliated rock containing hornblende crystals and minor plagioclase crystals, in a fine-grained matrix of feldspars, quartz, hornblende, biotite, and chlorite; occurs as lenses and pods in greenstone (g).
	g	**Greenstone**: Dark-greenish-gray fine-grained rock, generally unfoliated or poorly foliated but locally phyllitic, consisting of quartz with either actinolite, or muscovite and biotite, and with chlorite and epidote.

Source: Modified from Pratt, Walden P., Edwin T. McKnight and René A. DeHon. 1969. Geologic map of the Rico Quadrangle, Dolores and Montezuma Counties, Colorado. USGS Geologic Quadrangle Map GQ-797; *and* McKnight, Edwin T. 1974. Geology and ore deposits of the Rico District, Colorado. USGS Professional Paper 723.

The predominant ore deposits of the district consist of 1) massive sulfide replacement deposits in limestones of the Hermosa Formation, predominantly; 2) contact-metamorphic deposits of sulfides, specularite (micaceous iron oxide), and magnetite in limestones, chiefly of the Ouray and Leadville Limestones but also of the Hermosa Formation; and 3) veins on fractures and small faults in lower Hermosa sandstones and arkoses (McKnight, 1974).

Massive sulfide and contact-metamorphic deposits were the most productive of base metals with byproduct silver in the district. The most abundant sulfide mineral is pyrite (iron sulfide). Sphalerite (zinc sulfide) is second and galena (lead sulfide) is third in abundance. Least common of the base metals is chalcopyrite (copper-iron sulfide). These minerals are also associated with mine waste and mill tailings generated by the mining and processing of the produced ore.

The bedrock unit underlying the Dolores River valley in the Site area is the lower member of the Hermosa Formation, which is concealed by valley fill deposits (Figures 2-1 and 2-5). Ore production from the Silver Swan derived from lower Hermosa veins on fractures and replacement ore deposits in shaly limestone and limy shale containing massive sphalerite, galena, pyrite, chalcopyrite, and silver. The mine waste derived from such production contains these same minerals.

Mine waste was deposited on alluvium/stream gravel deposits (Qal) along and next to the Dolores River in the immediate vicinity of the adit (Figures 2-1). These deposits are confined to the valley of the Dolores River and their continuity in extent is not interrupted along the river in the townsite area. The thickness of these deposits in the valley is unknown but is presumed to be in excess of 10 feet. Because the Rico area is near the headwaters of the river, alluvial deposits are characterized by a very coarse texture (predominantly gravel, cobbles and boulders). The upper few feet of these deposits are exposed along the west bank of the river below of the toe of the waste pile.

Surficial deposits on the hillside that form the west and northwest side of the Site comprise 1) coarse-textured talus and slopewash (incudes fan on north side of the waste pile) (Qtw) and 2) landslide deposits of talus, slopewash (Ql).

There are no mapped potentially active faults within a 30-mile radius of Rico (Kirkham and Rogers, 1981). The Rico area is located within the Colorado Plateau seismotectonic province, which is characterized by relatively low historic seismicity. The primary potential hazards are re-activation of landslides and flood events along the Dolores River. No evidence of recent landslide movement has been observed. Indicators of instability, such as pistol-buttered tree trunks, slump features, and the like are not evident. The proposed remediation measures (Section 4.0) include design criteria for protection against reasonable flood events.

2.5.8 Aquifers

Ground water occurs in two flow systems in the Site area: shallow unconfined ground water in surficial alluvial/colluvial deposits and fan deposits; and in unconfined to semi-confined ground water in bedrock units.

2.5.8.1 Alluvial Flow System

Shallow ground water occurs in the alluvium/colluvium in the Dolores River valley, alluvial fan deposits that have formed at the mouths of tributary streams, such as the Sulphur Creek fan on the north side of the Site, and in slope wash and talus deposits. Ground-water recharge is by direct infiltration of snow melt and rainfall, and infiltration from tributary streams where they cross alluvial fan and slope wash deposits. Ground-water movement is down slope toward the Dolores River or tributary streams, or into bedrock through complex fracture systems. The Dolores River acts as a drain or line sink for discharge of shallow ground water where ground water discharges either directly to the river or to the wetlands along the river, or is lost through evapotranspiration. The thickness of the alluvium along the river is undetermined, but it is assumed to be less than 50 feet. Although there are no wells in the Dolores River valley bottom, the depth to ground water (water table) is generally expected to be less than ten feet and hydraulically in contact with wetland surface water bodies.

2.5.8.2 Bedrock Flow System

Ground water occurs in the bedrock complex that underlies and forms the mountain slopes on both sides of the Dolores River valley. Ground-water storage and flow in the bedrock system is predominantly associated with complex fracture systems and solution channels in limestone units where such exist. The principal source of ground-water recharge is infiltration from streams and alluvium/colluvium and by direct infiltration of snowmelt and rainfall. Water may discharge by hydraulic seepage to streams, alluvium/colluvium, springs, wells, or underground mine workings. Discharge of water from mines that intersect water-bearing fracture systems and mineral veins is a common occurrence in the Rico district and can significantly lower the water table in mined areas. For example, the water level in mines interconnected with the St. Louis tunnel has been lowered by about 450 feet and water continues to be drained from a large block of mineralized ground (McKnight, 1974) with seasonal discharge generally ranging from about 500 gpm to 1,900 gpm (PTI, 1995a). Similarly, on the west side of the Dolores River, the Silver Swan, Santa Cruz and other mines drain a significant block of mineralized bedrock, but with lower seasonal flows than the St. Louis tunnel system. For example, the historic flow data for the Silver Swan discharge indicate an average flow of about 50 gpm with a range of no flow to 193 gpm. The quality of the Silver Swan adit discharge is described in Section 2.6.2.

2.5.9 Ground-Water Monitoring and Supply Wells

"If groundwater contamination exists, or if the release has a potential to impact groundwater, the applicant should provide...listing of all wells within the one-half mile radius of the site, together with a map showing the locations of these wells;..."

There are no known ground-water monitoring or supply wells on the Site or within a one-half mile radius of the Site. As described in Section 2.5.4, there are only two supply wells in use in the Rico area and they are located in the Dolores River valley about 1.4 miles northwest of the Site (Figure 2-3).

2.5.10 Silver Swan Site Physical Characteristics

2.5.10.1 Area and Volume

The total tonnage of on-site wasterock piles material derived from the Silver Swan mine is about 21,000 tons (15,000 c.y.), covering a footprint area of approximately 2.0 acres (shown as the hatch in Figure 2-1). Copies of volume calculations are included in Appendix C4.

2.5.10.2 Surface Conditions

Two non-mineralized wasterock piles flank either side of the adit and are well vegetated. The pyritic wasterock materials are primarily composed of fine to coarse grained sand, gravel and larger sized materials and are generally devoid of vegetation except in isolated areas where topsoil has collected or small wetlands fed by the adit discharge have developed. Cedar Creek Associates (1995b and 1995c) has conducted a study characterizing the revegetation potential of tailings and borrow materials in the area and a revegetation plan for the Site. The revegetation study report and revegetation plan are provided under separate cover with this application.

The Silver Swan mine adit is the only known adit in the area. The adit is completely covered and discharging through cobble sized wasterock blocking the adit. The water quality of the discharge is described in Section 2.6.2.

North of the pyritic wasterock pile, in the Dolores River floodplain, lie natural wetlands fed by upland runoff and, to a lesser extent, adit discharge that seeps into the pile and emerges in the wetlands. The wetlands eventually discharge to the river at the northeast corner of the main pile, as described in more detail in Section 2.5.6.

A steep, narrow 76 acre drainage basin is situated directly west of the pile. The Sulphur Creek basin (521 acres) drains to a debris flow fan north of the pile and appears to contribute flow to the wetlands by infiltration into the fan and subsequent emergence into the wetlands. A majority of the Sulphur Creek flow is diverted along the fan away from the Site to the north and eventually discharges to the Dolores River.

Runoff from the pile generally discharges to the Dolores River or is captured by small depressions in the pile. Runoff estimates for the upland basins are discussed further in Section 4.3.

The main pyritic wasterock pile is situated directly on the west bank of the Dolores. It appears that portions of the pile have been or have the potential to be scoured and discharged to the river. Dames & Moore (D&M, 1981) performed a flood study of Dolores River which indicates that the existing pile and adit, except for a portion of the toe of the wasterock pile, is above the 100-year flood and SPF (Standard Project Flood) levels. The SPF flood corresponds to a ½ PMF (Probable Maximum Flood) flood.

2.5.10.3 Subsurface Conditions

The main pile may have been placed over an abandoned river meander or the Dolores river was diverted to the east to make room for the pile. Colluvium from the hills to the west may also underlie a small portion of the wasterock. No geotechnical or subsurface exploration data is available. However, the limited field observations conducted indicate that some component of groundwater flow, most of which is probably derived from infiltration of the discharge of the Silver Swan adit, is moving through the pyritic wasterock pile towards the Dolores River and, to a much lesser extent, the wetlands on the north side of the main pile.

2.5.11 Other Requested Information

- The following facilities or systems are not applicable to this application because they do not exist at the Site:

  (iv) facility process units and loading docks;
  (v) chemical and/or fuel transfer, and pumping stations;
  (vi) railroad tracks and rail car loading areas;
  (vii) spill collection sumps and/or drainage collection areas;
  (viii) wastewater treatment units
  (x) building drainage or wastewater discharge points;
  (xi) all above or below ground storage tanks;
  (xii) underground or above ground piping;
  (xiii) air emission control scrubber or refrigeration units;
  (xiv) water cooling systems or refrigeration units;
  (xv) sewer lines;
  (xvi) french drain systems;
  (xvii) water recovery sumps and building foundations;
  (xx) chemical or product storage areas;
  (xxi) leach fields; and
  (xxii) dry wells or waste disposal sumps.

2.6 Nature and Extent of Contaminants and Releases

2.6.1 Wasterock Assay Data

Silver Swan wasterock sampled by Anaconda Minerals Company in 1980 was assayed to determine the economic recoverability of lead, zinc, silver and gold. No data is available regarding concentrations of other constituents in these materials. Assay data for the wasterock is given in Table 2-5 (except gold) and Appendix C4. A summary of concentration data for the metals is presented below.

Lead. The average lead concentration is 15,200 parts per million (ppm) and ranges from 5,200 to 48,300 ppm.

Zinc. The average zinc concentration is 7,900 ppm and ranges from 3,000 to 19,600 ppm.

Silver and Gold. The approximate grade is 1.0 oz/ton silver (36ppm) and 0.005 oz/ton gold.

2.6.2 Adit and Wetland Discharge Water Quality

Historic adit water quality data for the periods 1980-1983 and 1991-1992 from several sources (Table 2-6) were reviewed and summarized in Table 2-7. In addition, three water samples were collected in June 1995: Sample A at the adit discharge point, Sample B on the edge of the wetland in a backwater about 63 feet downstream from the adit, and Sample C from one of the seeps emerging along the wasterock pile face that flanks the Dolores River. These water quality sample locations are identified in Figure 2-1 as stations SS-A, SS-B and SS-C respectively. Table 2-8 gives the results of field measurements for temperature, pH, specific conductance, Eh, iron (II), dissolved oxygen, and alkalinity. As the drainage exited the adit, it had a pH of 5.4, and an alkalinity of 427 mg/l as $CaCO_3$. Thus, it was not acid and it had significant neutralizing capacity. It also had low dissolved oxygen of 0.2 mg/l, and dissolved iron (II) of 1.6 mg/l. The dissolved oxygen increased to 6.0 mg/l and the dissolved iron (II) decreased to 0.4 mg/l within 63 feet of the adit, due to exposure to atmospheric oxygen. It appears the increased oxygen oxidized the iron (II) and precipitated it as an orange iron (III) hydroxide floc. The seepage from the wasterock pile (16°C) was significantly warmer than the adit discharge (8°C). It had a pH of 5.8, no measurable iron (II), and 3.7 mg/l of dissolved oxygen indicating that any iron in the water was present as suspended iron hydroxide.

TABLE 2-5
METALS CONCENTRATIONS IN THE SILVER SWAN WASTE ROCK[a]

Sample No.	Location No.	Lead (mg/kg)	Zinc (mg/kg)	Silver (mg/kg)
80-131-1	201A	6,100	3,000	14.4
80-131-2	201B	13,800	8,700	28.1
80-131-3	202	6,100	4,200	10.0
80-131-4	203A	23,100	14,600	45.6
80-131-5	203B	21,400	18,600	80.6
80-131-6	204	7,400	5,200	11.9
80-131-7	205	18,100	8,900	41.3
80-131-8	206	14,600	7,500	24.4
80-131-9	207	6,400	3,800	5.00
80-131-10	208	12,500	4,700	16.9
80-131-11	209	10,800	8,100	71.3
80-131-12	210	13,900	5,300	13.8
80-131-13	210A	19,300	15,600	30.6
80-131-14	211	5,200	6,900	26.3
80-131-15	211B	48,300	19,600	57.5
80-131-16	212A	22,200	9,700	30.6
80-131-17	212B	6,900	5,500	19.4
80-131-18	213	17,200	5,400	26.3
80-131-19	214	17,200	9,400	60.3
80-131-20	215	9,200	5,000	26.6
80-131-21	216	25,600	5,300	30.0
80-131-22	217	23,100	7,300	30.6
80-131-23	218	17,200	3,300	34.1
80-131-24	219	7,400	4,700	162
80-131-25	220	8,100 U	8,100	3.4
Minimum		5,200	3,000	3.44
Maximum		48,300	19,600	162
Arithmetic mean		15,244	7,936	36.0
UCLM		19,704	9,714	55.6

[a] See Appendix C4 for waste pile volume and assay data sheets.
U = Not detected; value represents detection limit
UCLM = Upper 95 percent confidence limit of the arithmetic mean (calculated assuming a lognormal distri
Note: For non-detect values, half the detection limit was used in all calculations

TABLE 2-6

Summary of Historical Surface Water Quality Data Sources for Rico Area

Description	Data Available	Frequency	Hardness?	Source of Data[a]
Surface Water				
1980 and 1981 surface water data	Dissolved, Total	Monthly (OCt 80-Oct 81)	Yes	CORE for Gibbs & Hill (1981)
1982 Surface Water Data	Dissolved, Total, Total Recoverable	Three times	Yes	CORE for SRK (1983)
1983 Surface Water Data	Dissolved, Total, Total Recoverable	Monthly	Yes	CORE for SRK (1984)
1984 Surface Water Data	Dissolved, Total, Total Recoverable	Quarterly	No	CORE for SRK (1984)
1984 Surface Water Data	Dissolved, Total	Once	No	FIT Team (E&E, 1985)
1989-1993 Surface Water Data	Dissolved, Total	Sporadic (1-10 times during 4 years)	No	USBR (1995)

[a] All available historic surface water and ground-water data is provided in "Summary of Surface Water and Ground-Water Data for Rico, Colorado" (PTI, 1995).

TABLE 2-7

Silver Swan Adit
Surface Water Quality Data Summary
(Sampling Stations DR28T And D-09)

Date Sampled	Consultant	Flow	pH	Hardness (as CaCO3)	Alkalinity (as CaCO3)	Ag-D	Ag-T	As-T	Cd-D	Cd-T	Cu-D	Cu-T	Fe-D	Fe-T	Hg-T	Pb-D	Pb-T	Mn-D	Mn-T	Zn-D	Zn-T
		(gpm)	(s.u.)	(mg/l)	(mg/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
30-Oct-80	Gibbs & Hill	22	7.5						10	10 U	10	10 U	50 U	9860	0.3 U	50 U	50 U	2050		3400	3400
20-Nov-80	Gibbs & Hill	45	7.4						20	20	10 U	10	50 U	6600	0.3 U	50 U	50 U	2050		2400	2400
17-Dec-80	Gibbs & Hill	45	7.2						10 U	10 U	10 U	10	3060	6900	0.3 U	50 U	50 U	2180		2300	2500
21-Jan-81	Gibbs & Hill	31	7.2	868					10 U	10 U	10	10	1810	8000	0.3 U	50 U	50 U	2420		2800	2800
23-Feb-81	Gibbs & Hill	36	7.4	830			5.7		10 U	10 U	10 U	10 U	3100	8400	0.3 U	50 U	50 U	2500		4200	4200
23-Mar-81	Gibbs & Hill	45	6.9	855			0.1 U		1 U	4	4	5	3550	5200	0.05 U	1 U	1 U	2650		2800	3000
22-Apr-81	Gibbs & Hill	67	6.6	676			0.1 U		2.2	2.2	1 U	1	2160	3640	0.05 U	1 U	1 U	1080		1300	1400
11-May-81	Gibbs & Hill	54	7.0	755			0.1 U		1.2	1.2	1	1	3050	3660	0.05 U	6	6	1670		1800	1800
21-May-81	Dames & Moore			788	555 L			10 U	10 U	10 U	10 U	10 U	5180	5200	0.3 U	50 U	10 U	1800	1800	1900	1900
1-Jun-81	Gibbs & Hill	27	7.2	755			0.1 U		3.2	3.3	1 U	1 U	860	2110	0.05 U	1 U	1 U	1820		2400	2400
24-Jun-81	Gibbs & Hill	27	7.3	768			0.1 U		1.8	1.8	16	26	50 U	3600	0.05 U	1 U	1 U	2250		2100	2600
14-Jul-81	Gibbs & Hill	27	7.3	734			0.1 U		3.4	4.4	1 U	22	120	8700	0.05 U	1 U	1 U	2050		3200	3200
12-Aug-81	Gibbs & Hill	18	7.1	884			0.1 U		7.2	7.5	1 U	1 U	130	6700	0.05 U	1	4	2690		2400	2700
11-Sep-81	Gibbs & Hill	22	6.9	846			0.1 U		3.3	3.3	1	7	3050	7000	0.05 U	1 U	9	2770		2700	2700
7-Oct-81	Gibbs & Hill	27	6.8	797			0.1 U		3	3	1	1	2140	5800	0.05 U	1 U	9	2060		2500	2600
16-Jun-82	SRK	72	6.7	955	588 L	0.05 U	0.07		8	8	26	27	50 U	380	0.01 U	1 U	1 U	1510	1610	2000	2000
17-Mar-83	SRK	99	7.2			0.1 U	0.1 U		1.6	1.1	11	11	50 U	220	0.05 U	1 U	3	480	510	1010	1010
12-Jun-83	SRK	193	6.9			0.1 U	0.1 U		4	4.5	30	32	150	970	0.05 U	1	3	1750	2050	3700	3900
22-Sep-83	SRK	144	6.8			0.1 U	0.1 U		1.9	1.9	13	26	50 U	310	0.1	1 U	1 U	400	400	1400	1400
15-Dec-83	SRK					0.1 U	0.1 U		2	1.9	16	23	70	210	0.05 U	1 U	1 U	380	380	1200	1200
12-Aug-91	USBR	0.0	5.7			4 U	4 U	30 U	1	0.8	5 U	5 U	4620	4650	0.1 U	30 U	30 U	1290	1240	780	765
14-Jul-92	USBR	1.8	5.7			0.1	0.3	59	0.15	0.4	6	23	3107	3260	0.3	2	7	493	732	31	79
15-Sep-92	USBR	51	6.8			10 U	10 U	10 U	5 U	5 U	25 U	25 U	8700	10300	0.03 U	3 U	7.4	1800	1800	910	980
1-Jun-95	PTI/ESA	50	5.4	568	427 F	0.08		3	3 U	3 U	10 U	10 U	1600	1680	0.5 U	9.04	11.6	621	634	343	361
Statistical Calculations - Undetects set to zero																					
Mean		50		791	523	0.02	0.34	12.4	3.1	2.9	6.0	9.8	1936	4723	0.017	0.8	2.5	1699	1116	2066	2137
Standard Deviation		45		96	85	0.04	1.34	26.1	4.5	4.3	8.7	11.1	2183	3172	0.064	2.2	3.7	763	656	1052	1076

D = Dissolved
T = Total recoverable
U = Not detected; value represents detection limit

CaC03 = Calcium Carbonate
Ag = Silver
As = Arsenic

Cd = Cadmium
Cu = Copper
Fe = Iron

Hg = Mercury
Pb = Lead
Mn = Manganese

Zn = Zinc
F = Field
L = Lab

Table 2-8

Silver Swan Surface Water Field Analysis

Location	Silver Swan - A	Silver Swan - B	Silver Swan - C
Sample Date	June 1, 1995	June 1, 1995	June 1, 1995
Discharge (gpm)	50	50	
Temperature (C)	8	12	16
pH	5.4	6.0	5.8
Conductivity (mS/cm)	0.40	0.94	0.77
Eh (mv)	370	333	379
Iron (II) (mg/l)	1.6	0.4	0.0
Iron (total dissolved) (mg/l)	1.8	0.5	0.0
Dissolved Oxygen (mg/l)	0.2	6.0	3.7
Alkalinity (as $CaCO_3$) (mg/l)	427	453	NM

Table 2-9 gives the concentrations of laboratory pH, sulfate, total-recoverable, dissolved, and suspended (by difference) metals in water from the same three locations. Most of the metals were initially in dissolved form as the water exited the adit. Within 63 feet of the adit in the backwater, 77 percent of the iron had oxidized and flocculated to suspended iron hydroxide due to exposure to atmospheric oxygen. Similar to iron, 93 percent of the lead precipitated or adsorbed onto the iron hydroxide and became suspended. In contrast, none of the cadmium or copper, only 11 percent of the manganese, and 14 percent of the zinc converted to suspended metal in that distance. The seepage from the wasterock pile contained one to two orders of magnitude higher concentrations of dissolved cadmium, copper, lead, and zinc than the adit drainage. Most (92 percent) of the iron was in suspended matter. Most of the other metals were dissolved. These results indicate that minimizing seepage through the wasterock pile should significantly improve the water quality of drainage from this site.

Table 2-9

pH, Sulfate, and Metal Concentration in Silver Swan Adit Drainage and Associated Wetlands and Seep (in μg/l, except sulfate /l and pH in s.u.) for Spring 1995

		pH	Sulfate	Cd	Cu	Fe	Mn	Pb	Zn
Adit	Total Recoverable			<3	<10	1680	634	11.6	361
	Dissolved	5.4	100	<3	<10	1600	621	9.04	340
	Suspended			0	0	80	13	2.56	21
	% Suspended *			0	0	5	2	22	6
Wetland 63 ft Downstream	Total Recoverable			<3	<10	2020	585	9.56	393
	Dissolved	6.0	100	4	<10	462	519	0.63	339
	Suspended			0	0	1558	66	8.93	54
	% Suspended			0	0	77	11	93	14
Seep Near Dolores River	Total Recoverable			99	107	766	753	633	14,600
	Dissolved	5.8	520	95	76	62	632	383	14,700
	Suspended			4	31	704	721	250	0
	% Suspended			4	29	92	16	39	0

* % Suspended = Suspended metal as % of total-recoverable metal

The June 1995 water sample in the wetland was collected on the edge of the wetland, in a backwater rather than in the main stream. In October 1995, a water sample was collected about the same distance from the Silver Swan adit, but in the main stream. Field measurements indicated that most of the iron was still in the reduced, Fe^{+2} form. These results suggest that water in the main stream does not have sufficient residence time to allow atmospheric oxygen to oxidize the reduced iron from the adit drainage. This finding has important implications for the design of a settling pond to allow the iron to oxidize and settle out.

Comparison of the results of the June 1995 sampling event with historic flow and water quality data (Table 2-10) and flow for the Silver Swan adit indicates that the flow in June 1995 was about average (50 gpm). The total iron concentration in June 1995 was about one-third its average value (1.68 vs. 4.72 mg/l). The total zinc concentration was about one-sixth of its average value (0.36 vs. 2.14 mg/l). Total manganese was about one-half of its average value (0.63 vs. 1.12 mg/l).

Table 2-10

Historic Water Quality-Silver Swan Adit Drainage

Analyte	Historic Average, mg/l	Historic Low Value, mg/l	Historic High Value, mg/l	No. of data points
pH		5.4	7.5	22
sulfate	272	100	520	24
total Fe	4.72	0.21	10.3	24
total Mn	1.12	0.38	2.05	10
total Zn	2.14	0.079	4.2	24

2.6.3 Dolores River Water Quality

2.6.3.1 Historic Water Quality Data Sources

Historical water quality data for the periods 1980-1984 and 1989-1994 from several sources (Table 2-6) was reviewed and evaluated for this application. Historical sampling locations and sample station designations are identified on Figure 2-6. The entire historical Dolores River water quality database associated with the Silver Swan application is presented in the report entitled, "Summary of surface water and groundwater data for Rico, Colorado" (PTI, 1995). A summary of the historical Dolores River surface water quality data for sampling stations on the Dolores River above Rico (sampling stations DR11T and D-05), below the confluence with Silver Creek (sampling stations D-06, DR49T, and SW-08), and below the Silver Swan is provided on Tables 2-11, 2-12, and 2-13, respectively.

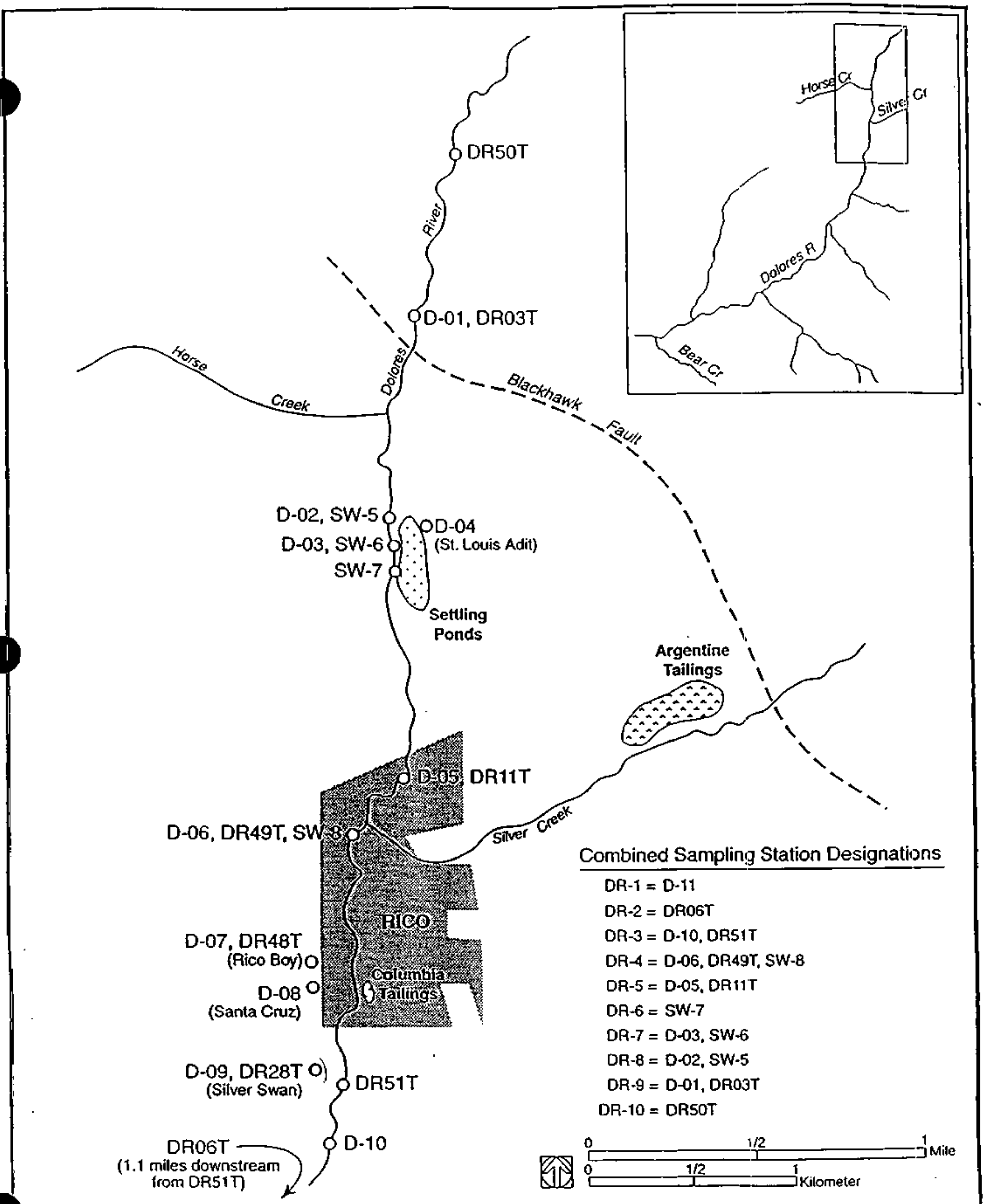


Figure 2-6 Sampling station locations on the Dolores River.

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TABLE 2-11

Dolores River Above Rico
Water Quality Data Summary
(Sampling Stations DR11T and D-05)

Date Sampled	Consultant	Flow	pH	Temp	DO	Hardness (as CaCO3)	Alkalinity (as CaCO3)	Ag-D	Ag-T	As-T	Cd-D	Cd-T	Cu-D	Cu-T	Fe-D	Fe-T	Hg-T	Pb-D	Pb-T	Mn-D	Mn-T	Zn-D	Zn-T
		(cfs)	(s.u.)	(cent.)	(mg/l)	(mg/l)	(mg/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
31-Oct-80	Gibbs & Hill	20	7.5								10 U	10	10 U	10 U	80	100	0.3 U	50 U	50 U	510		150	160
19-Nov-80	Gibbs & Hill	18	7.0		0.0133						10 U	10 U	10 U	10 U	50 U	170	0.3 U	50 U	50 U	450		100	270
16-Dec-80	Gibbs & Hill	15	6.7		0.01						10 U	10 U	10 U	10 U	50 U	180	0.3 U	50 U	50 U	470		180	210
20-Jan-81	Gibbs & Hill	16	7.0		0.008	317					10 U	10 U	10 U	10 U	60	330	0.3 U	50 U	50 U	410		110	110
26-Feb-81	Gibbs & Hill	16	7.1		0.011	334			20		10 U	10 U	10 U	10 U	60	540	0.3 U	50 U	50 U	500		110	110
24-Mar-81	Gibbs & Hill	18	7.1	4.4	0.009	328			75.1		1	1	7	7	50 U	500	0.05 U	1 U	1 U	480		80	100
22-Apr-81	Gibbs & Hill	91	7.2		0.0095	111			420		0.5	0.5	1 U	1 U	50 U	800	0.05 U	1 U	1 U	70		20	70
13-May-81	Gibbs & Hill	95	7.1		0.0107	102			0.1 U		0.2	0.2	1 U	1 U	50 U	210	0.25	1 U	1 U	100		80	90
3-Jun-81	Gibbs & Hill	381	7.1		0.0103	48			0.1 U		0.1 U	0.1 U	1 U	2	50 U	960	0.05 U	1 U	1 U	20		10	10
24-Jun-81	Gibbs & Hill	78	7.2		0.0094	90			2.1		0.1 U	0.1 U	8	8	50 U	50	0.05 U	1 U	1 U	50		40	110
14-Jul-81	Gibbs & Hill	149	7.5		0.0086	78			0.1 U		1.5	1.7	1	1	50 U	1610	0.05 U	1 U	1 U	30		30	90
12-Aug-81	Gibbs & Hill	66	7.4		0.0083	121		10	0.2		3.5	3.7	1 U	1 U	50 U	390	0.05 U	1	1	80		20	350
10-Sep-81	Gibbs & Hill	56	7.6		0.009	164			0.1 U		0.5	0.5	1 U	1 U	50 U	560	0.05 U	1 U	1 U	130		40	90
5-Oct-81	Gibbs & Hill	64	7.4		0.0092	135			0.1 U		0.1	1.5	15	15	70	5500	0.05 U	1 U	1 U	200		40	150
13-Apr-82	SRK	110	7.4		0.009	152	108 F	0.05 U	0.05 U		1.4	2.5	21	22	810	2980	0.01 U	6	9	190	270	160	160
17-Jun-82	SRK	304	7.0		0.0127	55	46 F	0.05 U	0.05 U		2.2	2.2	26	30	70	690	0.34	1 U	3	40	60	50	150
13-Oct-82	SRK	62	7.0		0.0138	169	98 F	0.05 U	0.05 U		1	1.2	1 U	1 U	70	160	0.01 U	1 U	9	250	250	150	160
25-Jan-83	SRK	14	7.1		0.011	260	145 L	0.05 U	0.05 U		1.5	0.9	2	2	50	300	0.01 U	1 U	1 U	420	420	120	200
23-Feb-83	SRK	20	7.1		0.0106			0.1 U	0.1 U		0.8	1	1 U	5			0.05 U	1 U	1 U			160	160
17-Mar-83	SRK	27	7.0		0.0097			0.1 U	0.1 U		1.2	0.6	1 U	1 U	50 U	160	0.05 U	1 U	2	300	310	130	150
26-Apr-83	SRK	115	6.7		0.0102			0.1 U	0.1 U		0.6	0.8	1 U	1 U			0.05 U	1 U	3			30	80
21-May-83	SRK	111	7.3		0.0123			0.1 U	0.1 U		1	1.2	9	8			0.05 U	1 U	4			100	70
12-Jun-83	SRK		7.0		0.0106			0.1 U	0.1 U		1.2	1.2	8	8	210	680	0.05 U	2	4	10 U	10 U	110	240
26-Jul-83	SRK		7.1		0.0093			0.1 U	0.1 U		3.1	1.2	4	6			0.05 U	2	4			140	110
30-Aug-83	SRK	78	7.4		0.0093			0.1 U	0.1 U		1.9	0.8	5	7			0.05 U	1 U	7			150	190
22-Sep-83	SRK	42	7.1					0.1 U	0.1 U		0.6	0.6	9	9	50 U	170	0.05 U	1 U	1 U	300	300	190	190
19-Oct-83	SRK							0.1 U	0.1 U		1	1	8	3			0.05 U	1 U	1 U			130	120
16-Nov-83	SRK	31	7.2					0.1 U	0.1 U		1.7	1.4	4	3	50 U	220	0.05 U	1 U	1 U	410	420	160	160
14-Dec-83	SRK							0.1 U	0.1 U		0.8	0.5	9	21	160	250	0.05 U	1 U	1 U	380	370	160	170
19-Jan-84	SRK							0.1 U	0.1 U		0.8	0.5	2	1 U			0.05 U	1	3			120	110
27-Mar-84	SRK							0.1 U	0.1 U		42	0.1	18	1 U	50 U	250	0.05 U	1 U	1 U	140	170	10 U	30
1-Jun-84	SRK							0.1 U	0.1 U		1.1	.0.9	11	2	120	860	0.05 U	1 U	4	60	50	20	40
12-Sep-84	SRK							0.1 U	0.1 U		0.4 U	0.7	1 U	2	50	200	0.05 U	1 U	1 U	140	150	20	50
6-Dec-84	SRK							0.1 U	0.1 U		0.4 U	0.4 U	1 U	1 U	70	270	0.05 U	1 U	1 U	160	170	20	20
17-Nov-89	USBR		7.6								1.5		20 U		0.11			5 U				160	
10-May-90	USBR		6.8					4.56	5.46	30 U	3 U	3 U	5 U	5 U	116	240	0.1 U	30 U	30 U	39.3	53.5	4.96	6.2
30-May-90	USBR																0.1 U						
11-Jul-90	USBR							4 U	4 U	30 U	3 U	3 U	5 U	5 U	9.58	112	0.1	30 U	30 U	43.9	47.4	21.3	42.6
7-Sep-90	USBR							4 U	4 U	32.9	3 U	3 U	5 U	5 U	3 U	74.6	0.1 U	30 U	39.7	114	113	53.7	29.3
14-May-91	USBR		6.5					4 U	4 U	30 U	0.2	0.3	5 U	5 U	110	419	0.1 U	30 U	30 U	19.7	41	4 U	6.95
4-Jun-91	USBR		6.6					4 U	4 U	30 U	0.3	0.3	5 U	5 U	61.2	288	0.1 U	30 U	30 U	41.1	50.2	22.9	23.9
16-Aug-91	USBR		6.4					4 U	4 U	30 U	0.4	0.2	5 U	5 U	24.2	218	0.1 U	30 U	30 U	130	133	38.9	23.6
23-Apr-92	USBR		7.2					0.1	0.1	6	0.3 U	0.3 U	5 U	13	182	240	0.2 U	1 U	1	50 U	80	10	30

TABLE 2-11 (CONTINUED)

Dolores River Above Rico
Water Quality Data Summary
(Sampling Stations DR11T and D-05)

Date Sampled	Consultant	Flow	pH	Temp	DO	Hardness (as CaCO3)	Alkalinity (as CaCO3)	Ag-D	Ag-T	As-T	Cd-D	Cd-T	Cu-D	Cu-T	Fe-D	Fe-T	Hg-T	Pb-D	Pb-T	Mn-D	Mn-T	Zn-D	Zn-T
		(cfs)	(s.u.)	(cent.)	(mg/l)	(mg/l)	(mg/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
14-Jul-92	USBR	68	6.8					0.1 U	0.1	6	0.3 U	0.3 U	5 U	10	145	219	0.2 U		1 U	50 U	76	17	26
14-Sep-92	USBR	20	7.2					10 U	10 U	1 U	5 U	5 U	25 U	25 U	100 U	170	0.03 U	3 U	20 U	180	210	20 U	44
8-Sep-93	USBR	49	6.8					2.6	2.2 U	0.63 U	1.4 U	1.4 U		3.5 U	3.5 U	139	0.074 U	7.6 U	7.6 U	128	135	10.2	26.6
Statistical Calculations - Undetects set to zero																							
Mean		74		4.4	0.0	164	99	0.56	13.1	4.5	1.6	1.1	3.7	4.1	67	561	0.015	0.3	2.1	197	169	79	109
Standard Deviation		84			0.0	99	41	1.98	67.1	10.3	6.1	2.1	6.2	6.8	135	976	0.063	1.0	6.2	174	127	61	78

D = Dissolved
T = Total recoverable
U = Not detected; value represents detection limit

CaC03 = Calcium Carbonate
Ag = Silver
As = Arsenic

Cd = Cadmium
Cu = Copper
Fe = Iron

Hg = Mercury
Pb = Lead
Mn = Manganese

Zn = Zinc
F = Field
L = Lab

Note: The St. Louis Ponds Water Treatment Plant began operating in April 1984.

TABLE 2-12

Dolores River Below Silver Creek
Water Quality Data Summary
(Sampling Stations D-06, DR49T, and SW-08)

Date Sampled	Consultant	Flow	pH	Temp	DO	Hardness (as CaCO3)	Alkalinity (as CaCO3)	Ag-D	Ag-T	As-T	Cd-D	Cd-T	Cu-D	Cu-T	Fe-D	Fe-T	Hg-T	Pb-D	Pb-T	Mn-D	Mn-T	Zn-D	Zn-T
		(cfs)	(s.u.)	(cent.)	(mg/l)	(mg/l)	(mg/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
20-Nov-80	Gibbs & Hill	21	6.8	1	12.2	403					10 U	10 U	10 U	10 U	50 U	240	0.3 U	50 U	50 U	670		420	420
16-Dec-80	Gibbs & Hill	14	6.9								10 U	10 U	10 U	10 U	50 U	130	0.3 U	50 U	50 U	450		600	600
20-Jan-81	Gibbs & Hill	17	7.1			328					10	10 U	10 U	10 U	50 U	320	0.3 U	50 U	50 U	430		200	200
26-Feb-81	Gibbs & Hill	9.0	6.9			332			0.2		10 U	10 U	10 U	10 U	60	500	0.3 U	50 U	50 U	500		190	190
25-Mar-81	Gibbs & Hill	16	7.1	5.5	9	353			0.1 U		1 U	2	1 U	1 U	50 U	510	0.05 U	1 U	1 U	510		150	170
22-Apr-81	Gibbs & Hill	100	7.0			114			0.1 U		0.8	0.8	1 U	1 U	50 U	820	0.29	1 U	1 U	90		60	100
13-May-81	Gibbs & Hill	102	7.1			96.78			0.1 U		0.7	0.7	1 U	1 U	50 U	200	0.25	1	1	90		80	110
3-Jun-81	Gibbs & Hill	446	7.1			47			0.3		0.1	0.1	1 U	27	50 U	1070	0.35	1 U	1 U	20		30	30
24-Jun-81	Gibbs & Hill	92	7.0			95			2.3		0.1 U	0.1 U	1 U	1 U	50 U	50	0.05 U	1 U	1 U	50		70	70
14-Jul-81	Gibbs & Hill	171	7.2			78			0.1 U		1.7	2	1	1	50 U	1760	0.05 U	1 U	1 U	30		40	530
12-Aug-81	Gibbs & Hill	71	7.2			120		10	0.5		3.1	3.6	1 U	1 U	50 U	410	0.05 U	1 U	1 U	80		50	90
10-Sep-81	Gibbs & Hill	57	6.9			148			0.1 U		0.4	1.2	1 U	1 U	50 U	580	0.27	1 U	1 U	130		80	90
5-Oct-81	Gibbs & Hill	90	7.2			137			0.1 U		0.5	1	1 U	1 U	50 U	530	0.05 U	1 U	1 U	120		80	120
13-Apr-82	SRK	95	6.5			161	110 F	0.05 U	0.2		3.9	4.5	16	16	2170	2640	0.01 U	10	10	330	380	500	960
17-Jun-82	SRK	469	7.9			54	44 F	0.05 U	0.05 U		2.2	4.3	19	20	50 U	560	0.03	1 U	15	30	60	40	110
13-Oct-82	SRK	70	7.5			160	96 F	0.05 U	0.05 U		1.2	1.2	1 U	1 U	80	160	0.01 U	1 U	3	200	210	160	230
25-Jan-83	SRK	14	7.0			270	151 L	0.05 U	0.05 U		1.5	1.4	2	3	50	270	0.01 U	1 U	1 U	420	420	200	300
23-Feb-83	SRK	17	7.1					0.1 U	0.1 U		1.1	1.8	1 U	3			0.05 U	1 U	1 U			230	230
17-Mar-83	SRK	27	7.0					0.1 U	0.1 U		1.7	0.5	2	2	70	180	0.05 U	1 U	2	290	290	190	190
26-Apr-83	SRK	150	7.0					0.1 U	0.1 U		1.3	1.3	1 U	10			0.05 U	1 U	5			200	250
21-May-83	SRK	137	7.3					0.1 U	0.1 U		1.2	1.4	21	7			0.05 U	2	3			160	160
12-Jun-83	SRK	925	7.2					0.1 U	0.1 U		1.2	1.6	7	7	200	720	0.05 U	1	3	70	70	90	430
26-Jul-83	SRK	269	7.2					0.1 U	0.1 U		3.7	1.3	4	8			0.05 U	1	5			90	80
30-Aug-83	SRK	81	7.4					0.1 U	0.1 U		1.7	1	6	6			0.05 U	1 U	5			140	240
22-Sep-83	SRK	45	7.1					0.1 U	0.1 U		0.6	1.1	9	8	50 U	210	0.05 U	1 U	1 U	290	290	200	200
19-Oct-83	SRK							0.1 U	0.1 U		1	0.9	7	2			0.05 U	1 U	1			150	150
16-Nov-83	SRK	37	7.4					0.1 U	0.1 U		1.9	1.8	6	3	50 U	260	0.05 U	1 U	1 U	390	390	190	190
14-Dec-83	SRK							0.1 U	0.1 U		0.8	0.8	4	3	80	290	0.05 U	1 U	1 U	390	390	220	230
19-Jan-84	SRK							0.1 U	0.1 U		1.5	0.7	6	1			0.05 U	1	3			200	190
27-Mar-84	SRK							0.1 U	0.1 U		21	0.9	45	1 U	50 U	330	0.05 U	1 U	1 U	150	170	160	150
1-Jun-84	SRK							0.1 U	0.1 U		0.8	0.4	32	4	50	930	0.05 U	1 U	5	50	50	50	60
12-Sep-84	SRK							0.1 U	0.1 U		0.5	0.7	1 U	2	50	230	0.05 U	1 U	1 U	120	140	50	80
14-Nov-84	EPA/FIT		6.7					5 U	5 U	10 U	5 U	5 U	5 U	8	40	199	0.1 U	2 U	5 U	140	141	90	74
6-Dec-84	SRK							0.1 U	0.1 U		0.4 U	0.4 U	1 U	1 U	50 U	310	0.05 U	1 U	1 U	160	170	60	70
8-Sep-93	USBR	43	6.8	19.4				2.2 U	2.2 U	0.6 U	1.4 U	1.4 U	3.5 U	3.5 U	106	192	0.074 U	7.6 U	7.6 U	130	136	14.2	58.6
Statistical Calculations - Undetects set to zero																							
Mean		133		8.6	10.6	181	100	0.43	0.11	0	1.9	1.1	5.3	4.0	106	521	0.03	0.5	1.7	226	220	155	210
Standard Deviation		198		9.6	2.3	116	44	2.09	0.41	0	3.8	1.1	10.1	6.2	407	549	0.09	1.7	3.3	180	130	128	186

D = Dissolved
T = Total recoverable
U = Not detected; value represents detection limit

CaC03 = Calcium Carbonate
Ag = Silver
As = Arsenic

Cd = Cadmium
Cu = Copper
Fe = Iron

Hg = Mercury
Pb = Lead
Mn = Manganese

Zn = Zinc
F = Field
L = Lab

Note: The St. Louis Ponds Water Treatment Plant began operating in April 1984.

TABLE 2-13

Dolores River Below Rico
Water Quality Data Summary
(Sampling Stations DR51T and D-10)

Date Sampled	Consultant	Flow	pH	Hardness (as CaCO3)	Alkalinity (as CaCO3)	Ag-D	Ag-T	As-T	Cd-D	Cd-T	Cu-D	Cu-T	Fe-D	Fe-T	Hg-T	Pb-D	Pb-T	Mn-D	Mn-T	Zn-D	Zn-T
		(cfs)	(s.u.)	(mg/l)	(mg/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
29-Oct-80	Gibbs & Hill	36	7.1						10 U	10 U	10 U	10 U	50 U	50 U	0.3 U	50 U	50 U	280		200	200
18-Nov-80	Gibbs & Hill	21	7.3						10 U	10 U	10 U	30	50 U	630	0.3 U	50 U	50 U	480		280	380
15-Dec-80	Gibbs & Hill	18	7.3						10 U	10 U	10 U	10	50 U	260	0.3 U	50 U	50 U	470		320	320
19-Jan-81	Gibbs & Hill	28	7.3	324					10 U	10 U	10 U	10 U	70	340	0.3 U	50 U	50 U	410		220	230
25-Feb-81	Gibbs & Hill	17	7.5	302			1470		10 U	10 U	10 U	10 U	50 U	270	0.3 U	50 U	50 U	250		180	180
26-Mar-81	Gibbs & Hill	12	7.6	411			0.1 U		2	3	1	1	50 U	260	0.05 U	1 U	1 U	530		310	340
22-Apr-81	Gibbs & Hill	95	6.9	121			0.1		0.9	1.2	1 U	1 U	50 U	730	0.05 U	1 U	1 U	110		120	150
13-May-81	Gibbs & Hill	107	7.3	102			0.1 U		0.5	0.5	26	26	50 U	200	0.48	1 U	1 U	90		100	220
3-Jun-81	Gibbs & Hill	431	6.9	48			0.1 U		0.2	0.3	1 U	12	50 U	1180	0.05 U	1 U	1	20		60	60
24-Jun-81	Gibbs & Hill	104	7.3	95			0.1 U		0.2	0.2	1 U	1	50 U	50	0.05 U	1 U	1 U	50		60	80
16-Jul-81	Gibbs & Hill	170	7.7	68			0.2		0.1 U	0.1	15	15	70	6800	0.05 U	1 U	1 U	30		40	50
12-Aug-81	Gibbs & Hill	75	7.4	129		10	0.7		3.6	3.6	10	10	50 U	960	0.05 U	1 U	54	120		130	210
11-Sep-81	Gibbs & Hill	65	7.3	159			0.1 U		0.5	0.8	1	1	50 U	550	0.05 U	1 U	4	170		140	140
5-Oct-81	Gibbs & Hill	85	7.1	149			0.1 U		1	0.3	1 U	1 U	50 U	810	0.05 U	3	3	140		100	160
14-Apr-82	SRK	135	7.1	156	107 F	0.05 U	0.05 U		1.9	2.3	7	7	50 U	2440	0.01 U	1 U	4	160	280	260	290
17-Jun-82	SRK		8.1	64	42 F	0.05 U	0.05 U		1.4	1.8	8	8	80	770	0.06	1 U	2	50	50	70	160
14-Oct-82	SRK	70	7.0	183	103 F	0.05 U	0.05 U		1	1.3	1 U	1 U	110	400	0.01 U	3	3	300	320	290	340
17-Mar-83	SRK	30	7.2			0.1 U	0.1 U		1.2	1	2	4	50 U	180	0.05 U	1	1	370	380	280	300
12-Jun-83	SRK		7.5			0.1 U	0.1 U		1.2	1.3	1	5	190	900	0.05 U	2	3	70	80	160	420
22-Sep-83	SRK		7.3			0.1 U	0.1 U		0.8	1.1	10	12	50 U	320	0.05 U	1 U	1 U	340	340	240	260
15-Dec-83	SRK					0.1 U	0.1 U		1	0.9	2	1 U	170	340	0.05 U	1 U	7	390	400	250	260
27-Mar-84	SRK					0.1 U	0.1 U		24	1.1	54	1 U	50 U	180	0.05 U	1 U	1 U	190	190	200	180
1-Jun-84	SRK					0.1 U	0.1 U		0.9	0.5	7	3	70	850	0.05 U	1 U	5	40	80	40	30
12-Sep-84	SRK					0.1 U	0.1 U		0.4	0.9	3	5	60	230	0.05 U	1 U	1 U	130	160	90	110
6-Dec-84	SRK					0.1 U	0.1 U		0.7	0.6	1	1 U	80	300	0.05 U	1 U	1 U	170	190	100	110
8-Sep-93	USBR	60	6.9			2.2 U	2.2 U	0.63 U	1.4 U	1.4 U	13.3	4.1	56.3	231	0.21	7.6 U	7.6 U	164	160	14.6	126
Statistical Calculations - Undetects set to zero																					
Mean		90		165	84	0.8	67	0	3.7	0.9	6.2	3.9	37	776	0.029	0.3	3.3	212	219	164	204
Standard Deviation		99		108	36	2.8	313		4.6	0.9	11.6	8.0	55	1325	0.101	0.9	10.5	154	122	94	105

D = Dissolved
T = Total recoverable
U = Not detected; value represents detection limit

CaC03 = Calcium Carbonate
Ag = Silver
As = Arsenic

Cd = Cadmium
Cu = Copper
Fe = Iron

Hg = Mercury
Pb = Lead
Mn = Manganese

Zn = Zinc
F = Field
L = Lab

Note: The St. Louis Ponds Water Treatment Plant began operating in April 1984.

2.6.3.2 Dolores River Water Quality

The water quality of the Dolores River in the vicinity of the Silver Swan adit is affected both by the quality of the Dolores River water flowing into Rico from upstream and by the presence of point and non-point sources in the vicinity of Rico (e.g., Columbia tailings, Santa Cruz adit). An evaluation of dissolved metals concentrations indicates that mean dissolved iron, cadmium, silver, and zinc concentrations increase in the Dolores River in the vicinity of the Silver Swan adit (Figures 2-7 through 2-11).

As described above, analytical data for Silver Swan adit seepage indicates that the seepage contains mean dissolved concentrations of iron, manganese, and zinc of 1936, 1699, and 2066 μg/L, respectively (Table 2-7). A comparison of the Dolores River water quality to numeric standards is provided in Section 3.2.

The Dolores River, below the Silver Swan adit, has a mean alkalinity of 84 mg/L as $CaCO_3$ (range of 42 to 107) and a pH range of 6.9 to 8.1. The high buffering capacity of the Dolores river is a result of the widespread existence of carbonate minerals in the Rico mining district. This important characteristic has prevented creation of a classic "acid mine drainage" problems in surface water in the Rico district.

2.7 Sources of Information

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Cedar Creek. September, 1995b. Revegetation Plan for Proposed Voluntary Remediation of Mining-Related Disturbances in Rico, Colorado. Prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants Inc., Fort Collins, Colorado. Cedar Creek Associates, Inc., Fort Collins, Colorado.

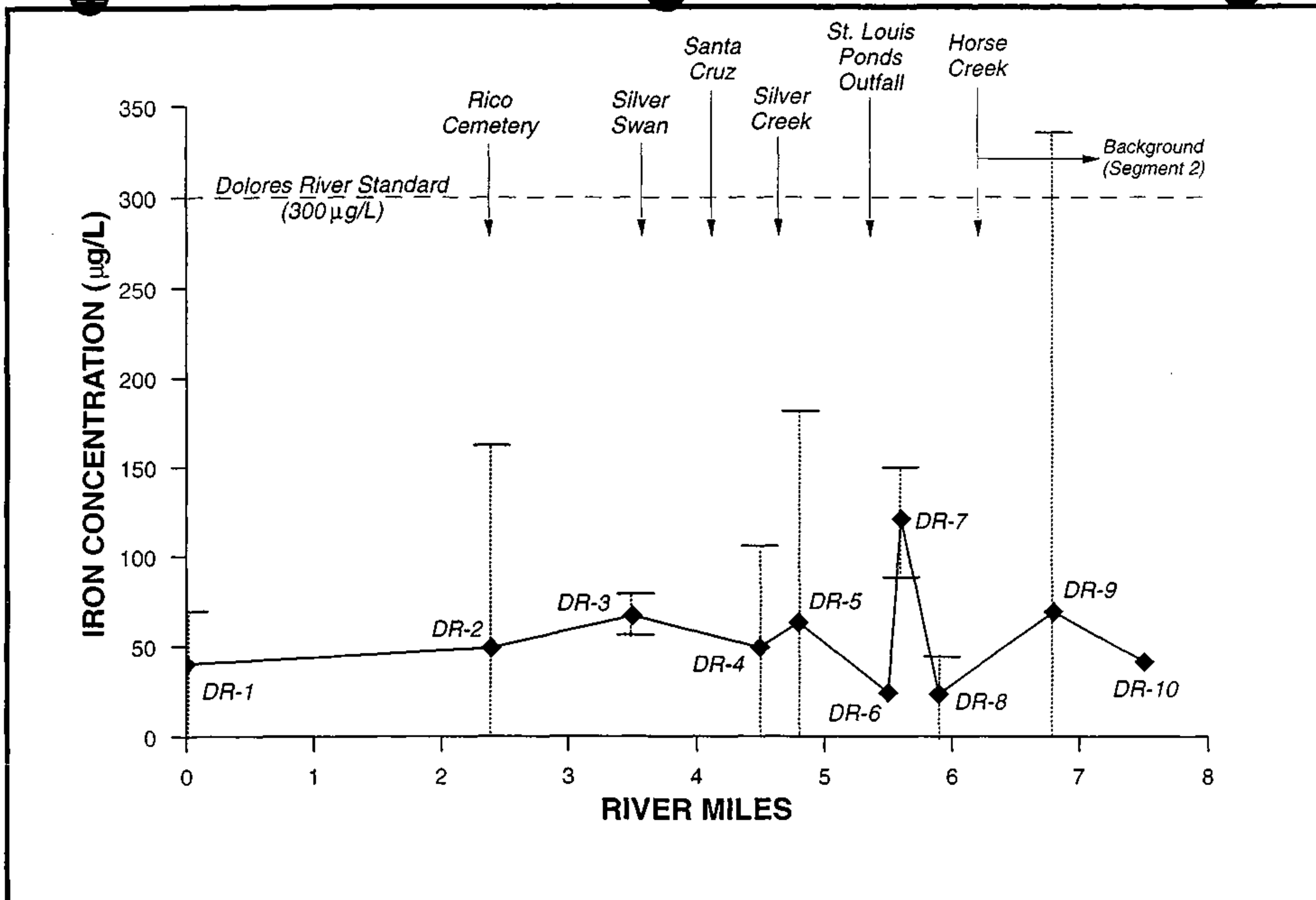

Figure 2-7 Iron concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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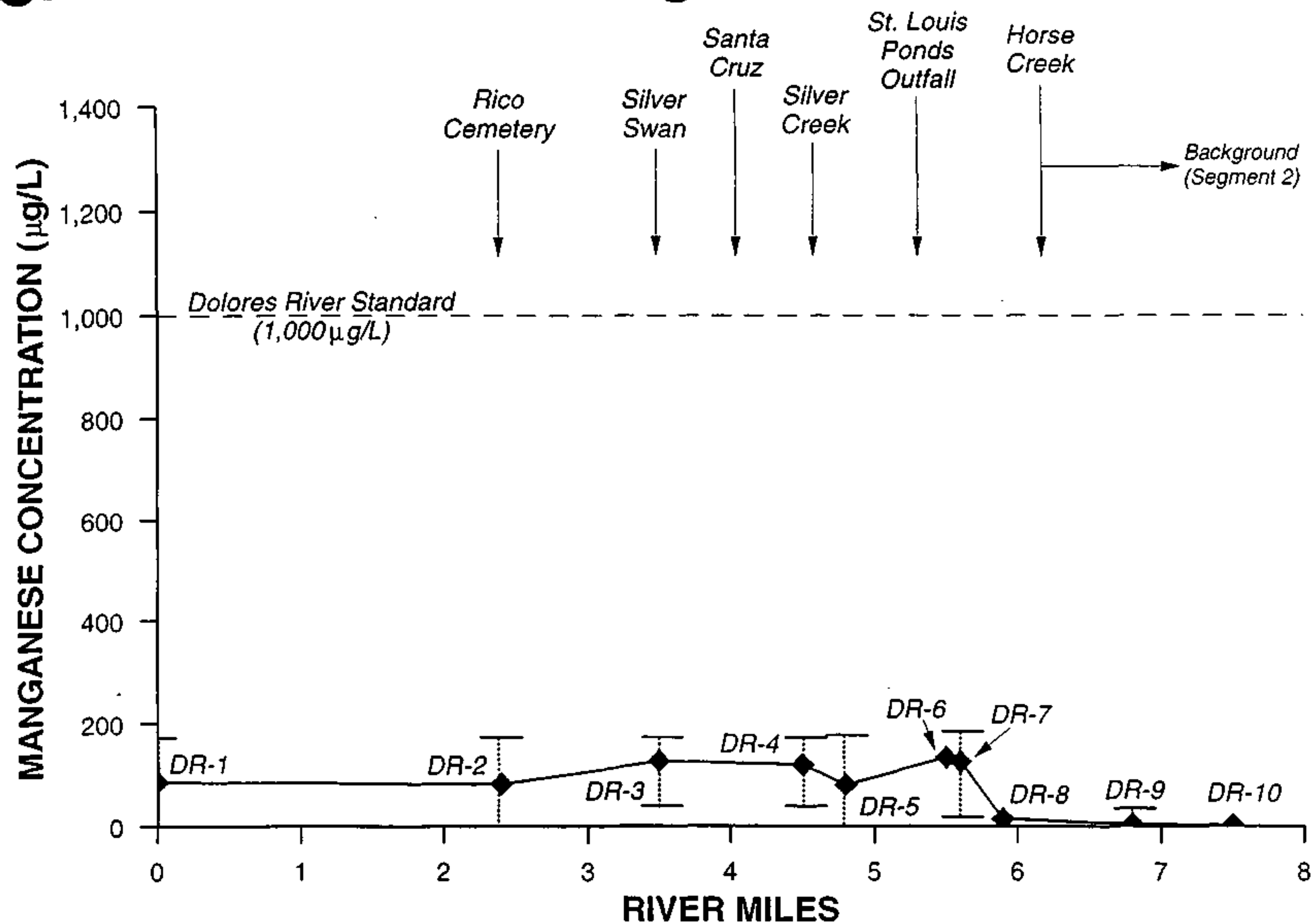

Figure 2-8 Manganese concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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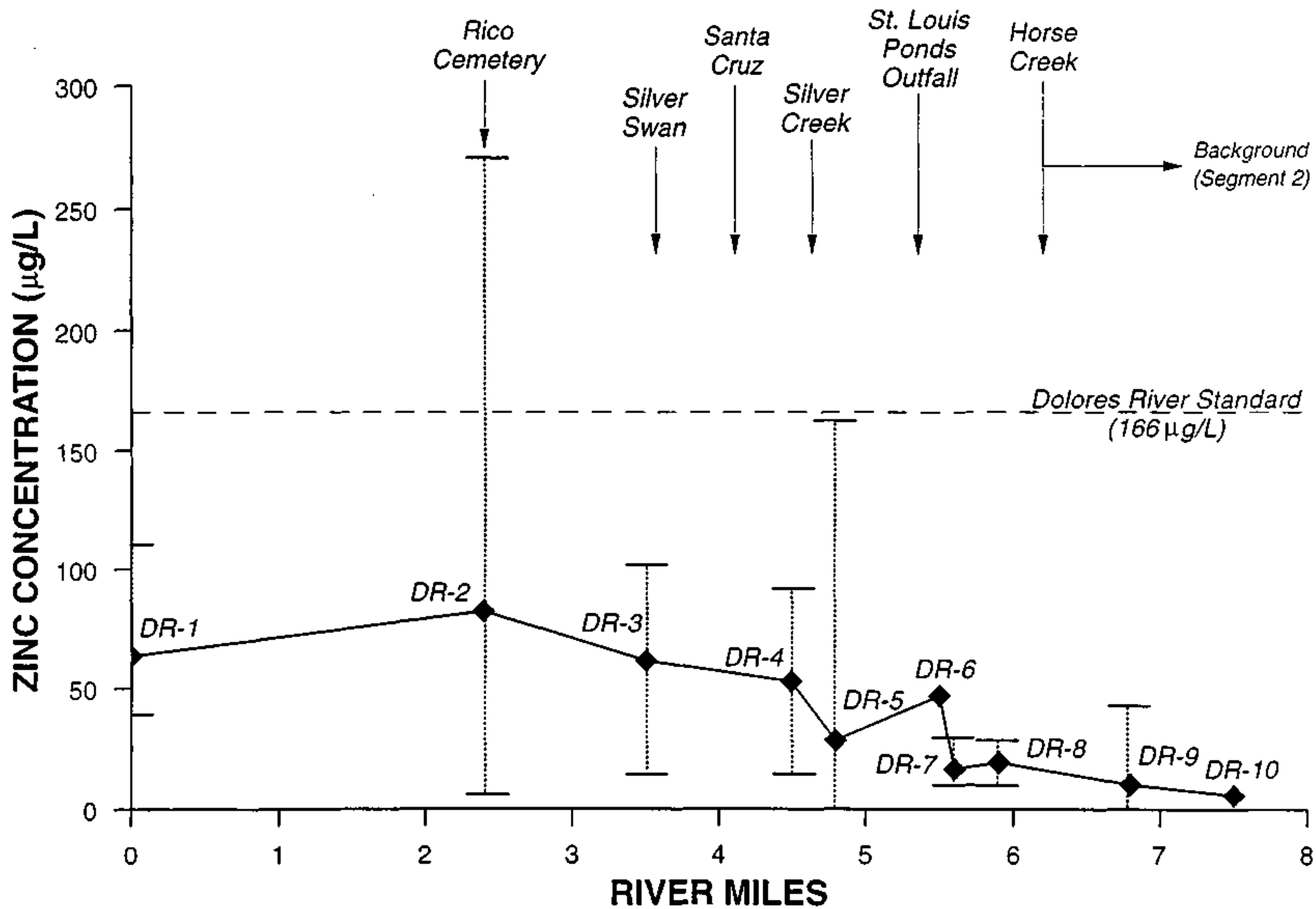

Figure 2-9 Zinc concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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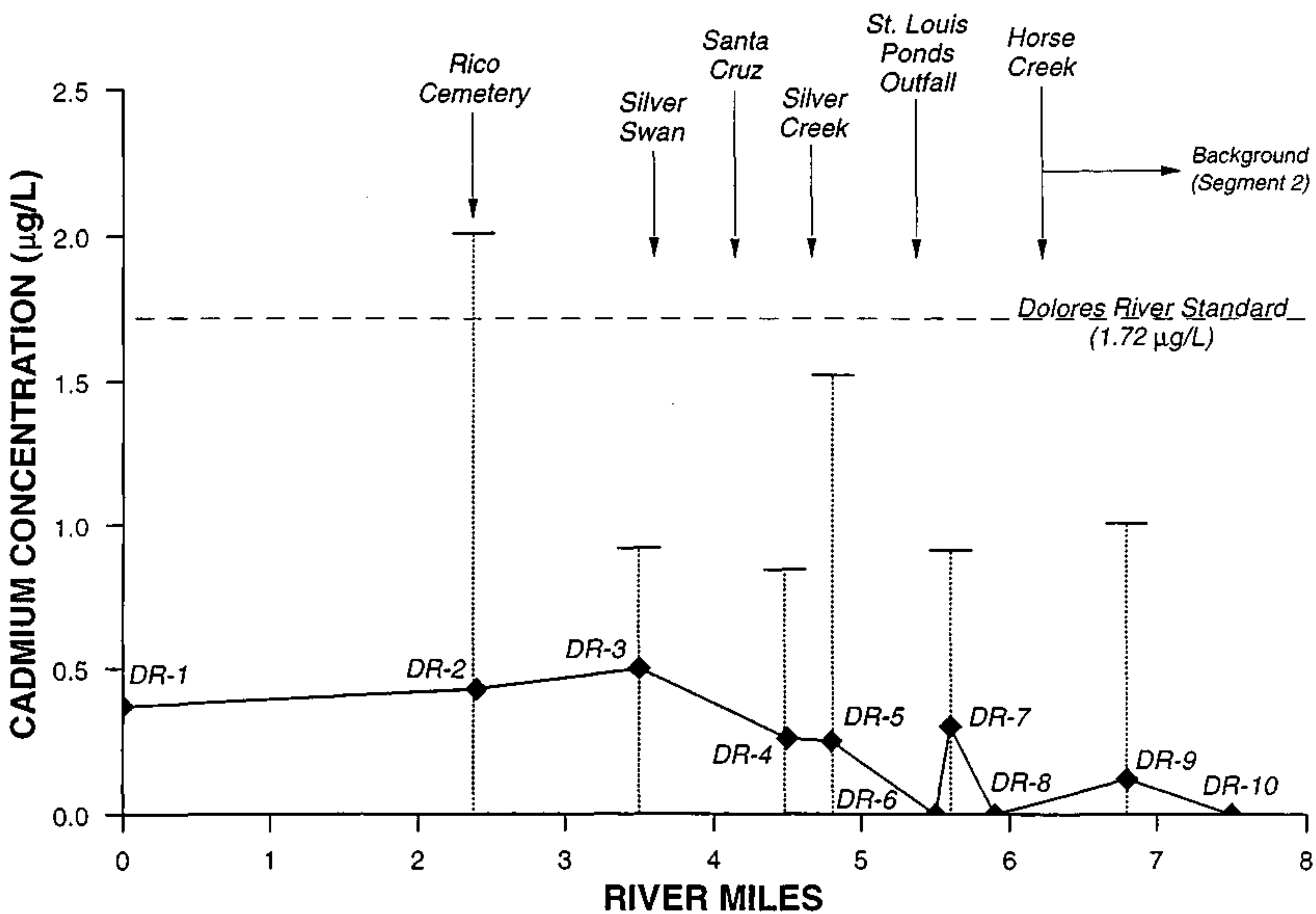

Figure 2-10 Cadmium concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

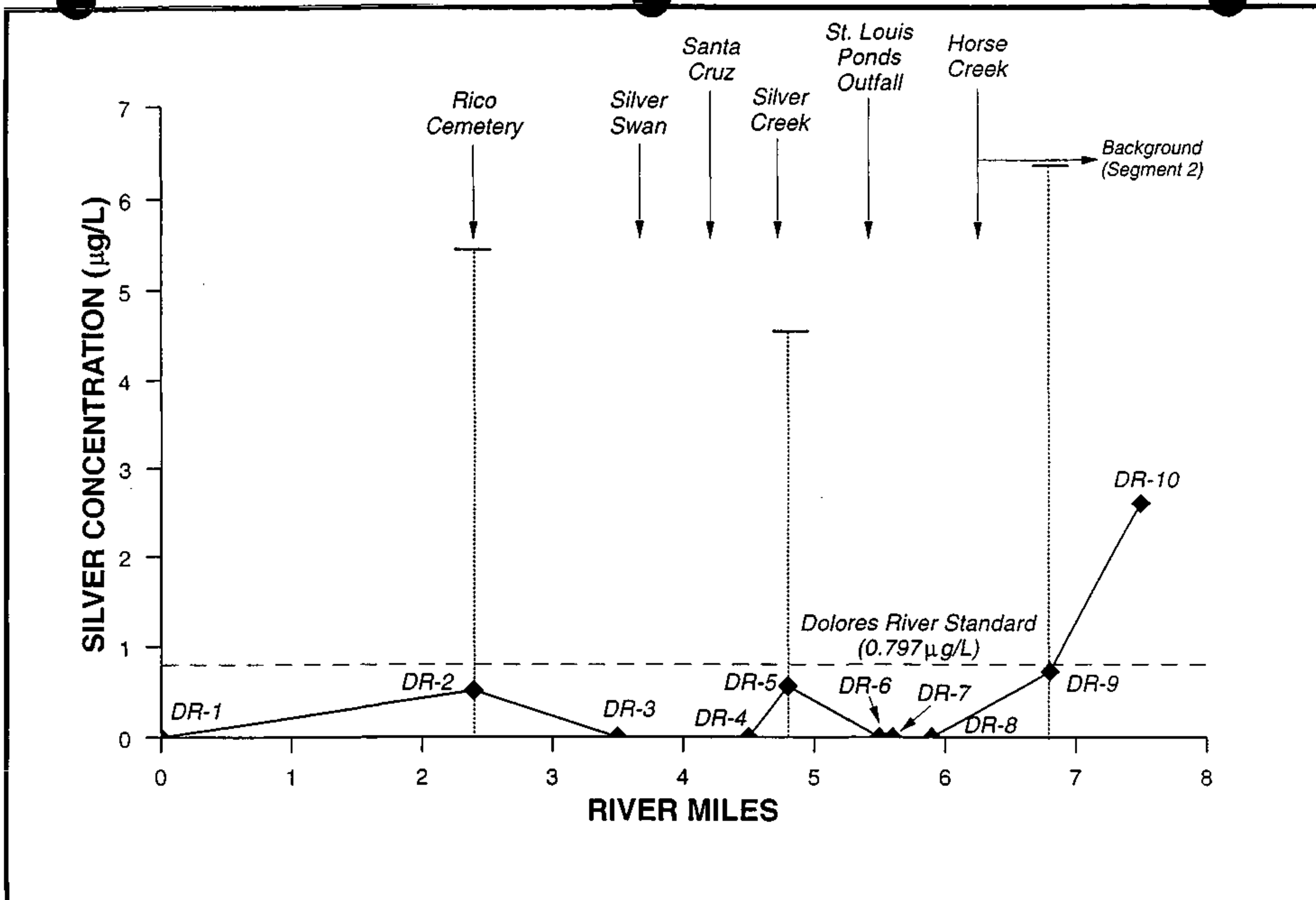

Figure 2-11 Silver concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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3.0 APPLICABLE STANDARDS/RISK DETERMINATION

"The applicant should provide a description of applicable promulgated state standards establishing acceptable concentrations of constituents (present at the site) in soils, surface water, or ground water."

"The applicant should provide a description of the human and environmental exposure to contamination at the site based on the property's current use and any future use proposed by the property owner."

3.1 Applicable Standards

3.1.1 Surface Water

The Silver Swan adit discharge and seepage from the Silver Swan wasterock flow into the Dolores River. Therefore, the current State of Colorado water quality standards for Dolores River Basin stream segments 2 and 3 are applicable to the Dolores River in the vicinity of Rico (CDH, 1995). The Site is located in segment 3. Segments 2 and 3 are described as:

No. 2 "Mainstream of the Dolores River from the source to a point immediately above the confluence with Horse Creek" (Figure 3-1).

No. 3 "Mainstream of the Dolores River from a point immediately above the confluence with Horse Creek to a point immediately above the confluence with Bear Creek" (Figure 3-1).

Segment 2 use classifications are defined as follows:

"Cold Water Aquatic Life - Class 1" - primary aquatic habitat.

"Recreation - Class 2" - stream segment where primary contact recreation does not exist and cannot be reasonably expected to exist.

"Water Supply" - stream segment where water quality is adequate for water supply and use exists or can be reasonably expected to exist.

"Agriculture" - suitable for agricultural use, although such use does not exist.

Segment 3 use classifications are defined as follows:

"Cold Water Aquatic Life - Class 1" - primary aquatic habitat.

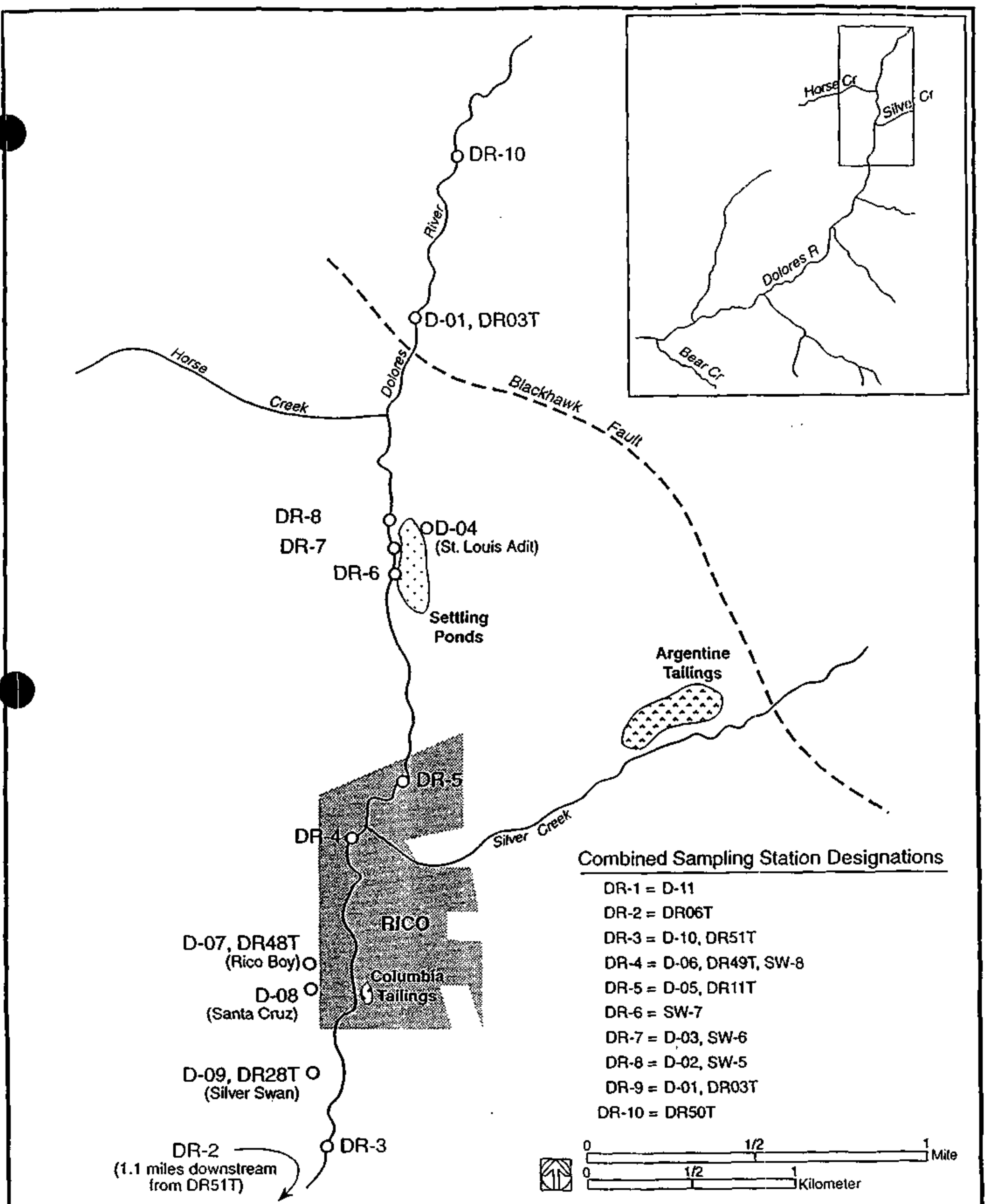

Figure 3-1. Sampling station locations on the Dolores River.

"Recreation - Class 2" - stream segment where primary contact recreation does not exist and cannot be reasonably expected to exist.

"Agriculture" - suitable for agricultural use, although such use does not exist.

The calculated table value standards (TVSs) and fixed standards for constiuents in segments 2 and 3 are listed in Table 3-1. The calculated values are based on an average mean hardness value of 170 mg/l provided by CDH (Anderson, 1995).

3.1.2 Mine Waste

There are no promulgated State Standards establishing acceptable concentrations of constituents in soils or mine waste.

3.2 Comparison of Dolores River Water Quality to Stream Standards

3.2.1 Approach to Use of Historic Data

As described in Section 2.6, aggregate water quality data for the Dolores River are available for the periods 1980-1984 and 1989-1993. Historic water quality sampling stations on the Dolores River are identified in Figure 3-1. The sampling station designation of "DR" has been assigned to aggregate historic sampling stations given different station designations by different sampling groups. River miles are measured upstream from the Montelores Bridge (mile 0) where USGS gauge station No. 0916500 is located. Segment 3 aggregate sampling stations include DR-1 through DR-8. Segment 2 aggregate sampling stations include DR-9 and DR-10.

Anaconda Minerals Company conducted remedial activities in 1984 for the St. Louis tunnel (adit) discharge north of the townsite (Figure 3-1). Remedial activities included the installation of a lime treatment plant at the St. Louis tunnel to improve discharge water quality. Because of these activities, only the historic water quality data for the Dolores River subsequent to remedial activities (1984 and thereafter) were used for comparison against the current state standards for segment 3 to account for any changes in river water resulting from treatment operations.

The use of historic data for comparison against acute and chronic standards is dependent on the type of sample collected. Samples composited over a thirty-day period are appropriate for comparison against chronic standards, while grab samples are appropriate for comparison against acute standards. Historic sampling events on the Dolores River were all based on grab samples. However, the CDH Water Quality Committee has indicated that the aggregate of grab samples should be used for comparison with chronic standards (Anderson, 1995).

TABLE 3-1

Current Water Quality Standards[a]

All metals dissolved, unless otherwise noted

Analyte	Standard (μg/l)	Equation or source
Dolores River (Segments 3): Hardness = 170 mg/l[b]		
Arsenic (total recoverable), chronic & acute	100	Agriculturally-based standard
Cadmium, acute	18.0	EXP {Ln(hardness) x 1.128 - 2.905}
Cadmium, chronic	1.72	EXP {Ln(hardness) x 0.7852 - 3.49}
Chromium III (total recoverable), chronic[c]	100	Fixed in stream classification table
Chromium VI, acute	16	Fixed in TVS
Chromium VI, chronic	11	Fixed in TVS
Copper, acute	29.2	EXP {Ln(hardness) x 0.9422 - 1.4634}
Copper, chronic	18.6	EXP {Ln(hardness) x 0.8545 - 1.465}
Iron, dissolved	300	Agriculturally-based standard
Iron, total	1,000	Agriculturally-based standard
Lead, acute	226	EXP {Ln(hardness) x 1.6148 - 2.8736}
Lead, chronic	8.25	EXP {Ln(hardness) x 1.417 - 5.167}
Manganese, chronic[d]	1,000	Fixed in stream classification table
Mercury (total), chronic[d]	0.01	Fixed in stream classification table
Nickel, acute	1,385	EXP {Ln(hardness) x 0.76 + 3.33}
Nickel, chronic	143	EXP {Ln(hardness) x 0.76 + 1.06}
Selenium, acute	135	Fixed in TVS
Selenium, chronic	17	Fixed in TVS
Silver, acute	5.07	EXP {Ln(hardness) x 1.72 - 7.21}
Silver, chronic	0.797	EXP {Ln(hardness) x 1.72 - 9.06}
Zinc, chronic	183	EXP {Ln(hardness) x 0.8473 + 0.8604}
Zinc, chronic	166	EXP {Ln(hardness) x 0.8473 + 0.7614}

a All equations and standards are from the "Classifications and numeric standards for San Juan River and Dolores River Basins, 3.4.0, effective May 30, 1995, Colorado Department of Health, Water Quality Control Commission.

b Hardness values provided by Dennis Anderson at the Colorado Department of Health, 6/5/95.

c Only chronic standards are listed for this stream segment, although formulas are available for acute standards.

d Fixed value given for chronic standard; no information given for acute standard.

Notes:

EXP = e raised to the indicated power
Ln = Natural logarithm
TVS = Table Value Standards(Anderson, 1995).

The Colorado Water Quality Control Commission has recommended that the 85th percentile of aggregate concentration data be used to compare such data against the standard. If the 85th percentile value is less than the standard, the Commission acknowledges that water quality standards have not been exceeded. Therefore, this value has been used to compare the historic data for each measured parameter with the current chronic standard for that parameter over the entire stream segment to determine compliance of Dolores River water quality relative to the standards. Additionally, to evaluate changes in water quality within the stream segment, the mean concentration for each compound was determined at each historic sampling location.

As stated in the CDH surface water regulations, "Both acute and chronic numbers adapted as stream standards are levels not to be exceeded more than once every three years on the average." The historic database used to evaluate the Dolores River comprise 9 years (1984-1993), thus these are three (3) allowable acute value exceedences. The number of detected values that exceed the acute standard was determined for segments 2 and 3.

All non-detects were set equal to zero. This approach is consistent with the data interpretation method used to develop the stream segment standards (CDH, 1995) and with the verbal guidance provided by CDH (Anderson, 1995, pers. comm.).

Background concentrations of site metals in surface water were evaluated with respect to both observed water quality and state standards. The Colorado Water Quality Control Commission states that on many stream segments, "elevated levels of metals are present due to natural or unknown causes (CDH 1995a)." For the purpose of determining background water quality in the Dolores River above Rico, metals concentrations were calculated from segment 2 (above the confluence with Horse Creek) sampling station data (D-01/DR07 and DR-10; Figure 3-1).

3.2.2 Results

Table 3-2 summarizes available water quality data for segments 2 and 3 of the Dolores River by constituent, sampling station and stream segment.

3.2.2.1 Background Segment 2

Except for silver, the historic data for segment 2 indicate metals concentrations below stream standards (Table 3-2). Both calculated average (0.9 ug/l) and 85th percentile (3 ug/l) concentrations of silver exceed the chronic standard (0.8 ug/l). There has been one measured exceedance of the acute standard for silver. Figures 3-2 through 3-4 illustrate the range and average concentartions for zinc, cadmium and silver, respectively for both segment 2 and segment 3 sampling stations.

TABLE 3-2. DOLORES RIVER SURFACE WATER QUALITY JUNE 1984-93

All units µg/L

PTI Station No.	Other identifiers	River mile	Number of samples	Arithmetic Mean[a]	85th Percentile[a]	Number of Exceedances of Acute Standard
ARSENIC (total): Developed state standard (chronic & acute) = 100 µg/L[b]						
DR-1	D-11	0.0	0	NA		
DR-2	DR06T	2.4	11	4.06		
DR-3	D-10/DR51T	3.5	1	0		
DR-4	D-06/DR49T/SW-8	4.5	2	0		
DR-5	D-05/DR11T	4.8	11	4.08		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	1	0		
DR-8	D-02/SW-5	5.9	1	0		
DR-9	D-01/DR03T	6.8	11	2.55		
DR-10	DR50T	7.5	1	0		
Segment 3		0.0 – 5.9	28	3.20	12.5	0
Segment 2		> 5.9	12	2.33	8.00	0
CADMIUM: Table value standard (chronic) = 1.72 µg/L; Table value standard (acute) = 18.0 µg/L						
DR-1	D-11	0.0	3	0.37		
DR-2	DR06T	2.4	12	0.43		
DR-3	D-10/DR51T	3.5	4	0.50		
DR-4	D-06/DR49T/SW-8	4.5	5	0.26		
DR-5	D-05/DR11T	4.8	14	0.25		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	3	0.30		
DR-8	D-02/SW-5	5.9	2	0		
DR-9	D-01/DR03T	6.8	10	0.12		
DR-10	DR50T	7.5	1	0		
Segment 3		0.0 – 5.9	44	0.32	0.85	0
Segment 2		> 5.9	11	0.11	0.42	0
COPPER: Table value standard (chronic) = 18.6 µg/L; Table value standard (acute) = 29.2 µg/L						
DR-1	D-11	0.0	3	8.67		
DR-2	DR06T	2.4	12	1.17		
DR-3	D-10/DR51T	3.5	4	6.08		
DR-4	D-06/DR49T/SW-8	4.5	5	6.4		
DR-5	D-05/DR11T	4.8	13	0.85		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	3	1.33		
DR-8	D-02/SW-5	5.9	2	0		
DR-9	D-01/DR03T	6.8	10	0		
DR-10	DR50T	7.5	1	0		
Segment 3		0.0 – 5.9	43	2.59	9.37	1
Segment 2		> 5.9	11	0.0	0.0	0
IRON: State developed standard (chronic) = 300 µg/L						
DR-1	D-11	0.0	3	40		
DR-2	DR06T	2.4	11	49		
DR-3	D-10/DR51T	3.5	4	67		
DR-4	D-06/DR49T/SW-8	4.5	5	49		

TABLE 3-2. (cont.)
All units µg/L

PTI Station No.	Other identifiers	River mile	Number of samples	Arithmetic Mean[a]	85th Percentile[a]	Number of Exceedances of Acute Standard
IRON (cont.)						
DR-5	D-05/DR11T	4.8	14	63		
DR-6	SW-7	5.5	1	24		
DR-7	D-03/SW-6	5.6	4	121		
DR-8	D-02/SW-5	5.9	2	23		
DR-9	D-01/DR03T	6.8	11	69		
DR-10	DR50T	7.5	1	41		
Segment 3		0.0 – 5.9	44	59	114	NA[c]
Segment 2		> 5.9	12	66	174	NA[c]
LEAD: Table value standard (chronic) = 8.25 µg/L						
Table value standard (acute) = 226 µg/L						
DR-1	D-11	0.0	3	0		
DR-2	DR06T	2.4	10	0.4		
DR-3	D-10/DR51T	3.5	4	0		
DR-4	D-06/DR49T/SW-8	4.5	5	0		
DR-5	D-05/DR11T	4.8	13	0		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	3	0		
DR-8	D-02/SW-5	5.9	2	0		
DR-9	D-01/DR03T	6.8	10	3.3		
DR-10	DR50T	7.5	1	0		
Segment 3		0.0 – 5.9	41	0.098	0.75	0
Segment 2		> 5.9	11	3.01	13.4	0
MANGANESE: State developed standard (chronic) = 1,000 µg/L						
DR-1	D-11	0.0	3	87		
DR-2	DR06T	2.4	10	82		
DR-3	D-10/DR51T	3.5	4	126		
DR-4	D-06/DR49T/SW-8	4.5	5	120		
DR-5	D-05/DR11T	4.8	13	81		
DR-6	SW-7	5.5	1	134		
DR-7	D-03/SW-6	5.6	3	126		
DR-8	D-02/SW-5	5.9	2	15		
DR-9	D-01/DR03T	6.8	10	4.6		
DR-10	DR50T	7.5	1	2.1		
Segment 3		0.0 – 5.9	41	92.2	157	NA[c]
Segment 2		> 5.9	11	4.33	11.1	NA[c]
MERCURY (total): State developed standard (chronic) = 0.01 µg/L						
DR-1	D-11	0.0	3	0		
DR-2	DR06T	2.4	3[d]	0		
DR-3	D-10/DR51T	3.5	3[d]	0		
DR-4	D-06/DR49T/SW-8	4.5	4[d]	0		
DR-5	D-05/DR11T	4.8	7[d]	0		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	3	0		
DR-8	D-02/SW-5	5.9	2	0		

TABLE 3-2. (cont.)
All units µg/L

PTI Station No.	Other identifiers	River mile	Number of samples	Arithmetic Mean[a]	85th Percentile[a]	Number of Exceedances of Acute Standard
MERCURY (cont.)						
DR-9	D-01/DR03T	6.8	3 [d]	0		
DR-10	DR50T	7.5	0 [d]	NA		
Segment 3		0.0 – 5.9	26 [d]	0	0.0	NA [c]
Segment 2		> 5.9	3 [d]	0	0.0	NA [c]
SILVER: Table value standard (chronic) = 0.797 µg/L						
Table value standard (acute) = 5.07 µg/L						
DR-1	D-11	0.0	3	0		
DR-2	DR06T	2.4	11	0.51		
DR-3	D-10/DR51T	3.5	4	0		
DR-4	D-06/DR49T/SW-8	4.5	5	0		
DR-5	D-05/DR11T	4.8	13	0.56		
DR-6	SW-7	5.5	1	0		
DR-7	D-03/SW-6	5.6	4	0		
DR-8	D-02/SW-5	5.9	2	0		
DR-9	D-01/DR03T	6.8	9	0.72		
DR-10	DR50T	7.5	1	2.60		
Segment 3		0.0 – 5.9	43	0.30	1.47	1
Segment 2		> 5.9	10	0.91	3.08	1
ZINC: Table value standard (chronic) = 166 µg/L						
Table value standard (acute) = 183 µg/L						
DR-1	D-11	0.0	3	63.3		
DR-2	DR06T	2.4	12	82.0		
DR-3	D-10/DR51T	3.5	4	61.2		
DR-4	D-06/DR49T/SW-8	4.5	5	52.8		
DR-5	D-05/DR11T	4.8	14	28.5		
DR-6	SW-7	5.5	1	47.0		
DR-7	D-03/SW-6	5.6	3	16.7		
DR-8	D-02/SW-5	5.9	2	19.5		
DR-9	D-01/DR03T	6.8	10	10.4		
DR-10	DR50T	7.5	1	5.80		
Segment 3		0.0 – 5.9	44	50.4	111	2
Segment 2		> 5.9	11	10.0	24.2	0

[a] Non-detect results were set to zero when calculating the mean and 85th percentile.
[b] Standard is total recoverable metals, but only total metals data were available.
[c] Only chronic standard was developed based on historical data.
[d] Excluding 1989-91 and 1993 data from Bureau of Reclamation report due to problems with data quality.
NA = Not applicable

Notes:
All metals reported as dissolved unless otherwise noted.
Hardness value of 170 mg/L was obtained from Colorado Department of Health Water Quality Control Commission.

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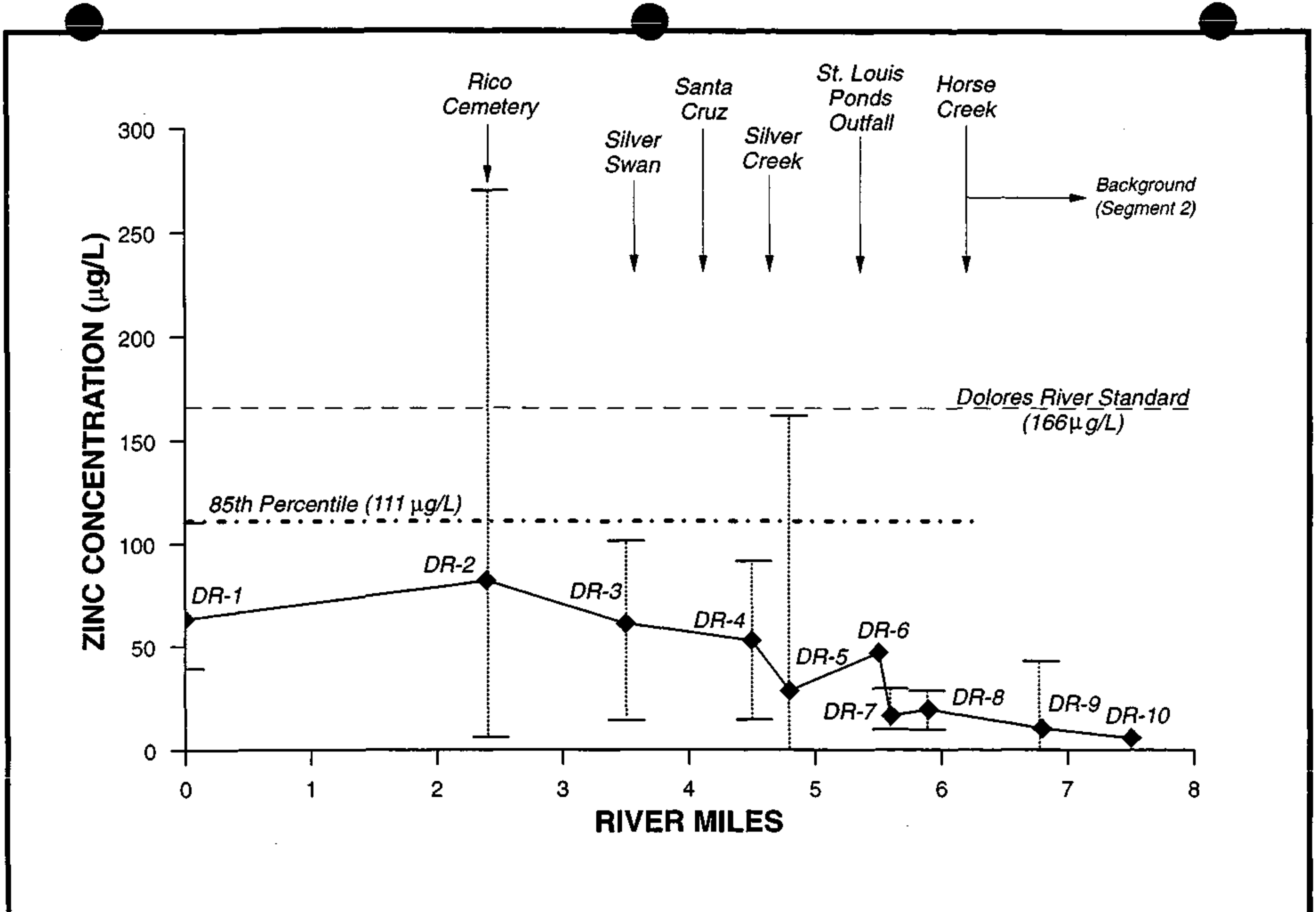

Figure 3-2. Zinc concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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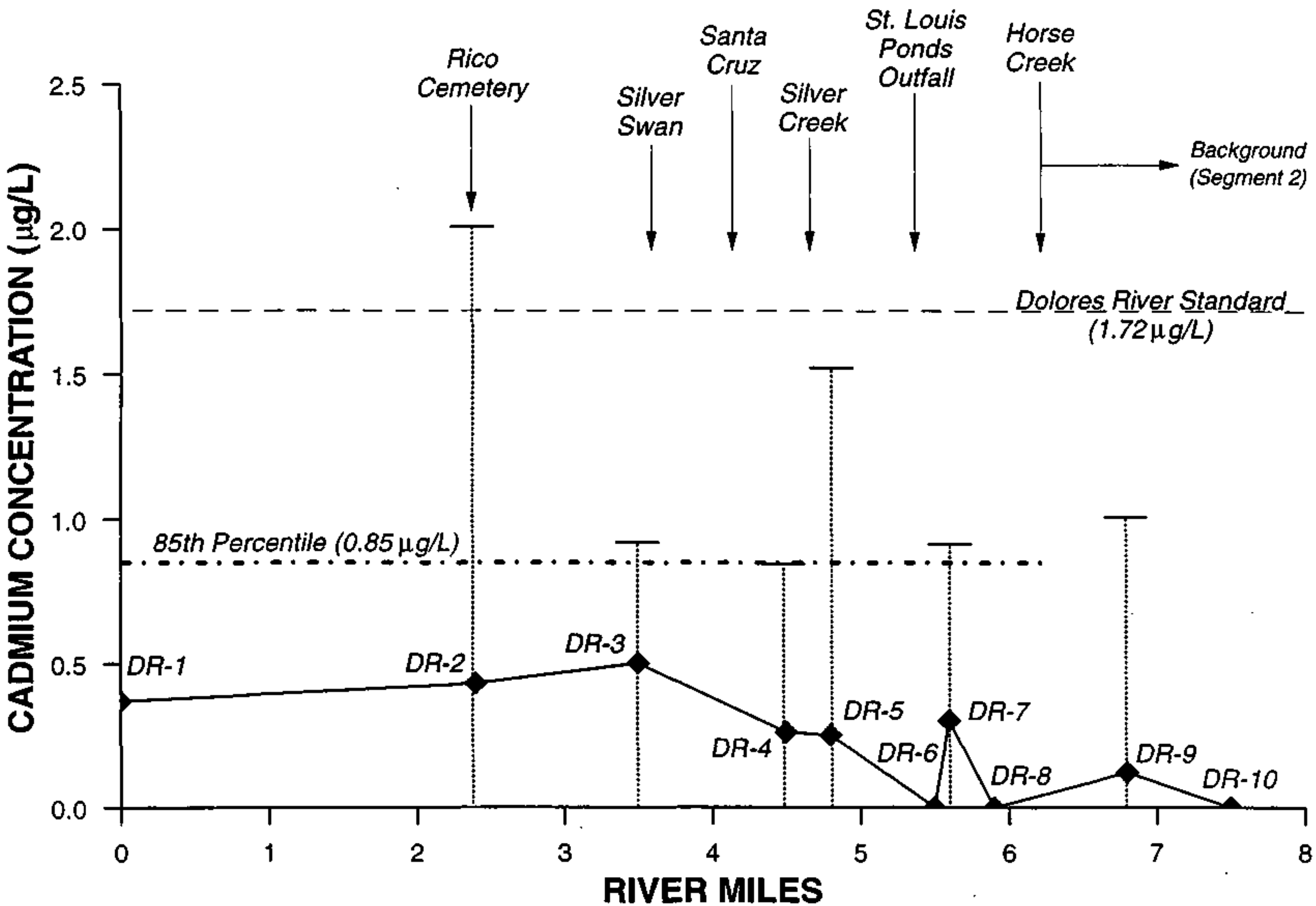

Figure 3-3. Cadmium concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

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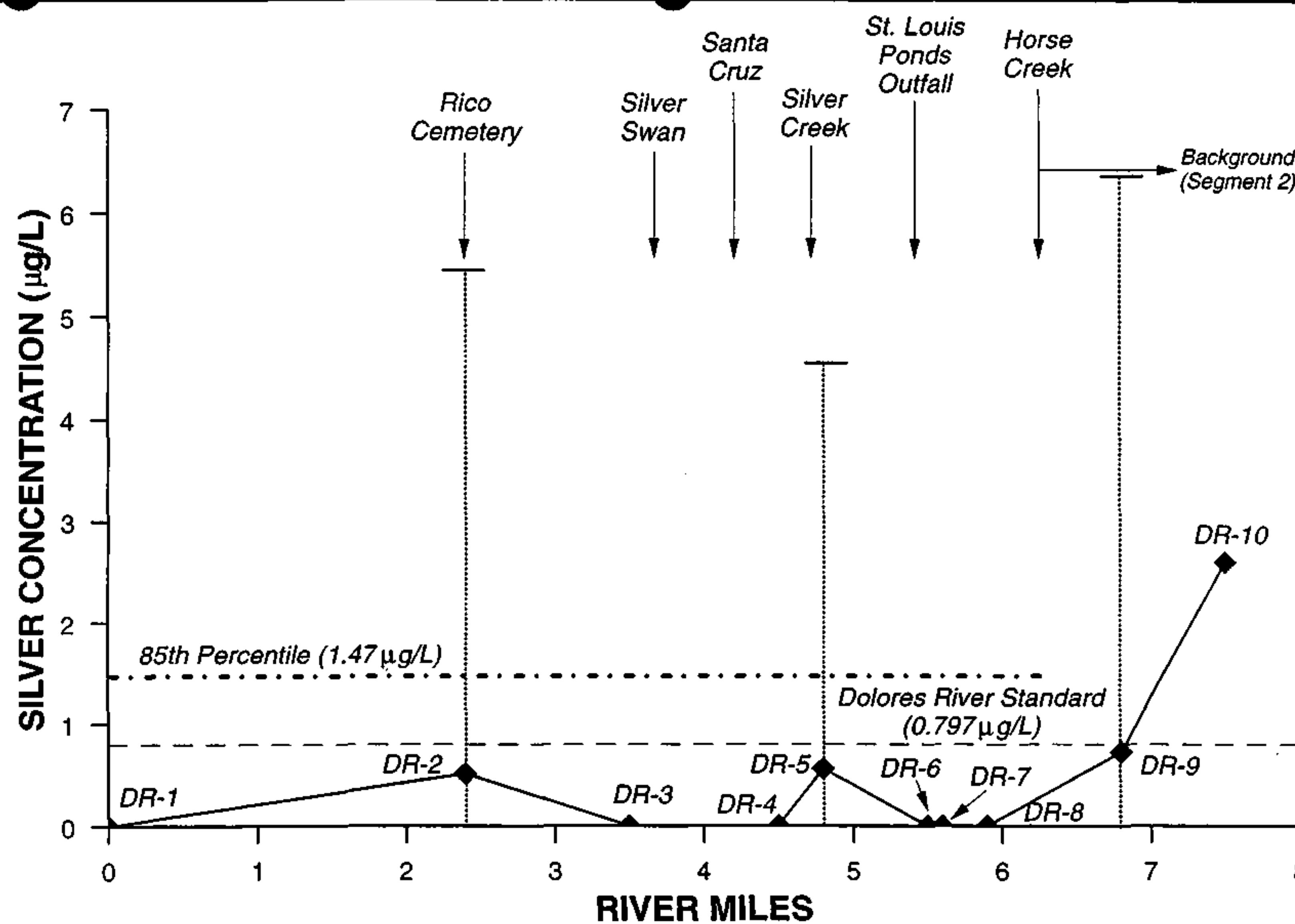

Figure 3-4. Silver concentrations (mean [◆], maximum, and minimum) in the Dolores River (June 1984 - 1993). [River miles are measured upstream from Montelores Bridge (mile 0)].

3.2.2.2 Segment 3

Except for silver, the historic data for segment 3 in the Rico area indicate metals concentrations below stream standards. The average concentration of silver (0.3 ug/l) is below the chronic stream standard (0.8 ug/l). The calculated 85th percentile concentration of silver (1.47 ug/l) is above the chronic stream standard. Background concentrations of silver contributed by segment 2 accounts for the exeedance. The historic data also indicate one (1) measured exceedance each of the acute standards for copper and silver, and two exceedances of the acute standard for zinc.

3.2.3 Conclusions

The historical water quality data for segments 2 and 3 indicate the following:

- Except for silver, concentrations of heavy metals in the Dolores River in the Rico area are below their respective stream standards.
- Concentrations of silver in segment 2 are above the chronic stream standard and account for concentrations above the standard in the Dolores River in segment 3.
- In general, heavy metals loading to the Dolores River increases due to various point and non-point sources as the river passes through the Rico area.
- Point and non-point sources contributing to heavy metals loading in the river include: 1) mined and unmined mineralized areas in the district; 2) drainage from underground workings, such as the St. Louis tunnel, Silver Swan, Santa Cruz, and Rico Boy adits; 3) any seepage from or direct contact with mine waste or mill tailings; and 4) metals-bearing tributaries, such as Silver Creek.

3.3 Risk Considerations for Mine Waste

Mine waste material was previously assayed by Anaconda Minerals Company to determine the economic recoverability of lead, zinc, copper, gold, and silver. (See Section 2.6.1.) No data are available for other potential elements of concern (e.g., arsenic, cadmium, and manganese). However, these elements are closely associated with lead in ores from the Rico mining district. They are also found in mine wasterock associated with ore deposits. Therefore, lead levels in such wasterock materials would essentially drive any health risk assessment and final remedial action for all elements of concern.

The key consideration in assessing risk associated with mine wastes at the Site is the extent of human or environmental exposure. Given the non-residential land use plan and lack of opportunity for direct contact, human exposure pathways are considered negligible. In addition, to ensure protectiveness of human health and to protect against environmental releases, the proposed reclamation plan for the site includes a combination of the drainage/erosion control measures, waste consolidation, regrading of slopes and embankments, limestone amendments, soil cover, and revegetation. These measures will effectively eliminate any direct human exposure and control potential environmental risks.

3.4 References

Anderson, D. 1995. Personal communication (telephone conversation on July 24, 1995, with Jeff Writer, PTI Environmental Services, Boulder, CO). Colorado Department of Health, Denver, CO.

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4.0 VOLUNTARY CLEANUP PLAN

"The voluntary cleanup plan must address known or potential releases of contaminants considering the human health and environmental risks of those contaminants in both the present and future land use scenarios. The plan must demonstrate that either all applicable state standards will be met, or for contaminants where no standard exists, that the risk level has been reduced to an acceptable level (excess cancer risk of 10^6, or hazard index < 1).

The remediation alternative selected should be described in sufficient detail to allow the Department to evaluate whether or not the applicant will be capable of remediating all contamination identified at the subject property within the specified 24 month time limit set down in 25-16-306(4)(a)."

4.1 Introduction

The primary objectives of this Voluntary Cleanup Plan (VCUP) for the Silver Swan mine site ("Site") are to:

- Effectively minimize the potential for direct human health exposure to the wasterock at the site;
- Consolidate and stabilize the wasterock piles in-place from erosion and slope instability due to runon/runoff, floods and earthquakes, thereby preventing off-site dispersal of wastes;
- Implement source controls to reduce the generation of dissolved metals from the wasterock piles; and
- Intercept and treat adit discharges to reduce current metals loadings to the Dolores River to the degree practicable.

These objectives address the known or potential releases of contaminants at the site, as described and discussed in the environmental assessment (Section 2.0) and the applicable standards/risk determination (Section 3.0).

The design bases and remediation techniques utilized in developing the proposed plan are described in Section 4.2. The design bases include specific regulatory requirements, best management practices (BMPs), applicable precedent from other sites, and standard engineering practice. The remediation techniques encompass hydrologic controls, reclamation cover, slope stabilization, passive wetlands treatment, and institutional controls.

The proposed conceptual remedial design for the Silver Swan site is described in detail in Section 4.3. As noted above, the plan includes stabilization and source control of the wastes on-site. Specific wasterock remediation measures to be implemented involve:

- Flattening of slopes on the wasterock pile susceptible to erosional instability;
- Consolidation of the wasterock pile;
- Grading to route offsite surface water (rainfall and snowmelt) around the wastes (runon control), and grading to shed incident rainfall and snowmelt from the wastes in a non-erosive manner (both of which contribute to limiting infiltration of water into the wastes);
- Compaction and revegetating of the surface and slopes of the wasterock piles; and
- Providing erosion protection (using riprap, gabions or equivalent means) against flooding in the Dolores River adjacent to the site.

The existing adit discharges will be intercepted in an excavated trench and treated in an enhanced wetlands system. This passive treatment system provides for aerobic precipitation and settling prior to discharge to the Dolores River.

Other aspects of the VCUP are described in Sections 4.4 through 4.9. These are summarized briefly as follows:

- Short- and long-term risks associated with the implementation (construction) and operation of the VCUP are relatively low and fully manageable; all of the proposed remediation measures are technically feasible;
- Operations and maintenance (O&M) requirements have been specifically minimized to the extent practicable as part of the conceptual design, and are simple and fully implementable;
- Specific mechanisms to be considered for insuring land use is consistent with the VCUP will be determined and executed as part of the VCUP implementation process. Some of the mechanisms currently being evaluated include application of Rico planning and development regulations, dedication of land parcels to town ownership, use easements, restrictive covenants, and conservation easements.
- Discussions regarding permit or other approval mechanisms for measures under the VCUP are currently being pursued with federal and state agencies. These permits would pertain to water quality discharge matters and the conduct of clean-

up activities on the banks of the Dolores River. Any permit requirements will be structured to support the remedial nature of the proposed activities and are expected to dovetail with VCUP components described herein. The remedial nature of activities to be conducted under the VCUP, which technically qualify as on-site "removal or remedial actions" under CERCLA, also raise the prospect of permit waivers under Section 121(e)(1) of CERCLA.

- The proposed plan can be implemented within the required 24-month time frame, assuming timely reviews and permit approvals and barring extreme weather conditions.

4.2 Summary of Remediation Techniques

4.2.1 Design Basis

The design bases for the various elements of remediation at the several sites included in this VCUP have been developed to meet the objectives discussed in Section 4.1 above and the more specific purposes associated with the remediation techniques as summarized in the subsections below. The remediation techniques proposed and the bases for their conceptual design have been developed, in part, by appropriate application of selected Best Management Practices (BMP) such as those presented by Colorado Mined Land Reclamation Division (1988) and Idaho Mining Advisory Committee (1992), and in general accordance with the relevant reclamation practices of the Mineral Rules and Regulations (Colorado Mined Land Reclamation Board, 1995). In addition, techniques or measures developed for and/or applied successfully at other mining sites in generally similar conditions in Colorado are incorporated as appropriate in the conceptual designs. Design criteria or standards are based on these BMPs, rules and regulations, and/or precedents noted where possible. In all cases, and especially where specific guidance is otherwise absent, standard engineering practice is applied in all of the conceptual design. In the discussions following, the various remedial measures proposed are briefly described, their purpose(s) is identified, and key design standards are presented. More detailed and comprehensive descriptions of the specific measures and how they will be applied at each site are presented in Section 4.3.

4.2.2 Hydrologic Controls

4.2.2.1 Runon Control

Practice: Runon controls are intended to prevent upland offsite surface water from coming into contact with mine waste or mine drainage. The structures envisioned for remediation of the Silver Swan site described herein are earthen dikes, ditches, drop structures/chutes, and energy dissipators (e.g., riprap plunge pools). These structures are appropriately protected from erosion under the design runon flows. This protection may be provided by the gradation of the earth materials used in the structures themselves, revegetation, riprap, or other materials (e.g., geocell mattress, gabions, grouted riprap) depending on the flow velocities and depths.

Purpose: The purpose of diversion structures is to intercept and re-route upland surface water flows away from waste deposits and/or contaminated discharges at the site to be remediated. The structures are sized such that the estimated offsite consequences if their capacity is exceeded are not significant given the dilution effects associated with the larger flow events.

Design Standards: The design standard adopted to meet the objectives of this measure is the 100-year frequency precipitation event.

4.2.2.2 Runoff Control

Practice: Runoff controls include measures to provide for controlled runoff from areas containing mine waste. Measures applicable to the Silver Swan site include contouring and grading of the wasterock piles, and ditches and/or dikes to convey the collected runoff flows offsite in a controlled manner. Reclamation cover measures, discussed separately below, also provide for runoff control by mitigating the potential for erosion of the wastes. Eliminating runon, as discussed above, is important in limiting the source of runoff water to direct precipitation (i.e., rainfall and/or snowmelt). Similarly, grading the tops of wasterock piles so that runoff is away from pile slopes wherever feasible also is important in runoff control and minimizing erosion.

Purpose: Runoff controls are intended to shed water from areas containing mine waste in a manner that does not erode and transport the wastes offsite. Proper runoff controls contribute substantially to limiting infiltration of surface water into the wastes.

Design Standards: The design standard adopted for sizing and layout of runoff controls is the same as for runon controls as described above (i.e., 100-year precipitation event). Where feasible, the top surfaces of wasterock piles are graded to drain at 2 percent, and sideslopes are graded at 4H:1V. Surface grades up to a maximum of 10 percent may be used where required by topographic or other constraints.

4.2.2.3 Infiltration Control

Practice: Infiltration controls are measures or practices which reduce or eliminate infiltration of surface water into and through mine wastes and ultimately to ground water. Such controls include consolidation of waste materials to reduce the surface area susceptible to infiltration, compaction of the upper surface of the waste pile to reduce the rate of infiltration, and most importantly, minimizing the quantity and duration of surface water contact with the waste pile by runon/runoff controls.

Purpose: The primary purposes of infiltration controls are to limit the potential for uncontaminated water coming into contact with the waste materials and becoming contaminated, and to reduce the potential for flows through the waste materials transporting contaminants away from the site by surface seepage discharge or ground-water flow.

Design Standards: The standard adopted for compaction of the surface of wasterock or tailings piles (beneath the reclamation cover) is that the upper 12 inches of waste be of a compactable gradation, and that 95 percent of Standard Proctor maximum dry density (or 95 percent of maximum index density for soils with little or no fines) be achieved.

4.2.2.4 Drainage Stabilization

Practice: Drainage stabilization involves measures to prevent or minimize erosion of contaminated materials by or into a receiving stream, and to protect treatment facilities from damage during flood events. For the Silver Swan site, such flood protection is provided by construction of dikes to separate flood waters from waste materials, and appropriate protection for natural ground, dikes, treatment works, and the waste materials to withstand the erosive forces of the flooding. Erosion protection may be provided by riprap, gabions, grouted riprap, geosynthetic liners or systems, or other means appropriate to the flooding event and site conditions.

Purpose: The purposes of drainage stabilization and/or flood control measures is to prevent uncontrolled erosion and dispersal of wastes due to normal and flood flows in receiving streams at the site, and to protect surface water treatment facilities from damage under design flooding conditions. Similar to the case for runon/runoff controls, these measures are sized such that the estimated offsite consequences of exceedance of their capacity are not significant given the dilution effects associated with larger flood events.

Design Standards: Given the substantially higher flows involved and the potentially more significant consequences of dispersal of wasterock or tailings offsite associated with flooding versus runon/runoff, the design standard adopted to meet this objective is the 500-year frequency precipitation event. Protection of the wetlands treatment system facilities is provided to 100-year level, consistent with requirements for municipal/industrial waste water treatment plants.

4.2.3 Reclamation Cover

Practice: Reclamation cover encompasses methods and materials applied to the surface of mine wastes which can include soil, rock, amendments to soil, pavements (asphalt or concrete), geosynthetic liners, revegetation, or composite systems of two or more of these items. For the Silver Swan site, cover methods proposed include revegetation of a composite wasterock/borrow soil seedbed, or rock mulch (i.e., minimum 4 inches of erosion-resistant gravelly soil on slopes up to 4H:1V) applied directly to the compacted, unamended wasterock or tailings surface.

Purpose: Reclamation covers are intended to provide protection of the surface of mine wastes from wind and water erosion, and interrupt incidental direct human and/or environmental contact with the underlying wastes. Erosion protection effectively minimizes or eliminates uncontrolled dispersal of waste material offsite. The physical barrier of borrow soil in the revegetation areas or rock mulch in the non-vegetated cover areas effectively prevents incidental contact or ingestion of waste materials.

Design Standards: The 100-year precipitation event has been adopted as the basis of design for which erosion protection is to be provided.

4.2.4 Slope Stabilization

Practice: Slope stabilization encompasses measures and/or structures to prevent sliding or mass wasting of natural, cut or fill slopes which may result in uncontrolled release of mine wastes. Measures to be employed at the Silver Swan site involve grading wasterock and tailings piles with sufficiently gentle slopes, implementing runon/runoff and infiltration controls to reduce or eliminate pore pressures within the slopes, and providing erosion protection in areas where scour could result in destabilizing adjacent slopes.

Purpose: Important objectives of stabilizing slopes are to prevent uncontrolled release of mine wastes into adjacent receiving streams, and to maintain the integrity of other remedial measures including runon/runoff and infiltration controls.

Design Standards: The standards for static stability of waste material slopes are a factor of safety against sliding of 1.5 for long-term, steady seepage conditions, and 1.3 for short-term, non-earthquake loadings including during construction. Stability during earthquakes (seismic loading) should be provided to a degree commensurate with the consequences of failure, and generally consistent with (or no less stringent than) the level of flood protection to be provided (i.e., an earthquake frequency on the order of at least 100-year to 500-year recurrence). Factor of safety under earthquake loading should be at least greater than 1.0.

4.2.5 Passive Treatment of Mine Drainage

Practice: Passive treatment of mine drainage encompasses a wide range of practices, processes and/or facilities which can be natural, enhancement of natural systems, or constructed. Enlargement, enhancement and fuller utilization of existing wetlands are the basic treatment concept proposed for the Silver Swan site.

A variety of treatment mechanisms are envisioned including aeration, filtration, adsorption, plant uptake, aerobic and anaerobic (microbially mediated) precipitation, and sedimentation. The proposed wetlands treatment system provides an environment for precipitation and removal of dissolved metals from the inflows. The components of the passive treatment systems include: earthen dikes and liners to form shallow ponds (treatment cells); hydraulic structures (primarily of earthen construction) to collect and convey inflows, and route flows through and out of the system.

Purpose: The passive treatment system is intended to reduce the concentrations of dissolved metals in adit flows from existing conditions prior to their discharge to the Dolores River receiving streams. Where the treatment processes result in biological oxygen demand (BOD) in the discharge that may be detrimental to the receiving stream, this deficiency is to be mitigated before discharge.

Design Standards: The overall treatment objective is to decrease the current loadings to the receiving streams from adit discharges or seepage so that the instream standards in the Dolores River downstream of the site continue to be attained. The treatment efficiency is intended to be maximized to the degree feasible given the existing constraints of site topography, climate and practical implementation of the complex mechanisms of passive wetlands-type treatment.

4.3 Silver Swan Site Remedial Design

The VCUP should include: *"A detailed description of the remediation alternative, or alternatives selected, which will be used to remove, or stabilize contamination released into the environment, or threatened to be released into the environment;*

A map identifying areas to be remediated, the area where the remediation system will be located, if it differs from the contaminated areas, locations of confirmation samples, the locations of monitoring wells, areas where contaminated media will temporarily be stored/staged, and areas where contamination will not be remediated; and

Remediation system design diagrams showing how the system will be constructed in the field."

4.3.1 Introduction

The conceptual plan for remediation of the Silver Swan site addressed in this plan are described in the following subsections. The proposed remediation measures to be implemented are described in sufficient detail to document that the concepts are technically and economically feasible, constructable, and can be implemented within the required 24-month time limit set by statute. Design diagrams are presented which show conceptual layouts and cross-sections of major elements of the remediation. Prior to implementation of the proposed remediation, final design investigations and analyses will be performed, and construction drawings and technical specifications prepared. The specific layout, sizing, and construction materials will be determined during final design and may be different in some detail to the concepts presented below.

Geohazards. No substantive engineering geologic or geotechnical issues have been identified with any of the remedial measures proposed for the site. As discussed in Section 2.5.6, there are no known significant geologic hazards with the potential to disrupt the remedial measures proposed. The proposed grading and estimated materials properties of the wasterock will result in stable slopes under both static and earthquake loadings. Where new dikes must be constructed across wetlands with weak, saturated foundation conditions, the use of appropriate geotextiles will provide adequate construction and long-term stability.

As noted in separate discussions that follow, the major hazard at the site is flooding of the Dolores River. As necessary, earthen dikes with appropriate toe and slope erosion protection are proposed to mitigate this hazard.

Site Access. Access to the Silver Swan site is available on existing roads and by fording the Dolores River. Access to the site would be across the existing bridge to west Rico, except for equipment which is too heavy. Heavy equipment would ford the stream at a location as near the bridge and existing road as possible to minimize disturbance.

Construction Site Controls. Controls would be implemented during construction to implement the requirements of applicable federal, state or local permits, codes or regulations. In particular, construction drawings and specifications would identify and require implementation of appropriate Best Management Practices (BMPs) to protect the Dolores River from sedimentation during construction. These BMPs might include:

- Armoring of the river banks as necessary at the locations selected for fording the Dolores River;

- Temporary grading and berms to prevent runoff from disturbed areas to the Dolores River;

- Detention of runoff from disturbed areas before allowing discharges into the Dolores River; and

- Construction of the wetlands dikes before excavating and consolidating wasterock.

BMPs would also be employed to control dust and spillage during earthmoving operations. These would include dust suppression at grading sites and on haul roads, and proper loading of haul trucks to prevent spillage.

All on-site construction and related activities will be conducted in strict conformance with a Site Specific Safety and Health Plan to be developed prior to mobilization. A Site Safety Officer will be designated to ensure that the requirements of the plan are met, and that safe work practices are implemented. Preliminary personal air monitoring and experience at other similar sites suggests that health risks will be minimal during earthmoving operations using appropriate BMPs.

4.3.2 Conceptual Design

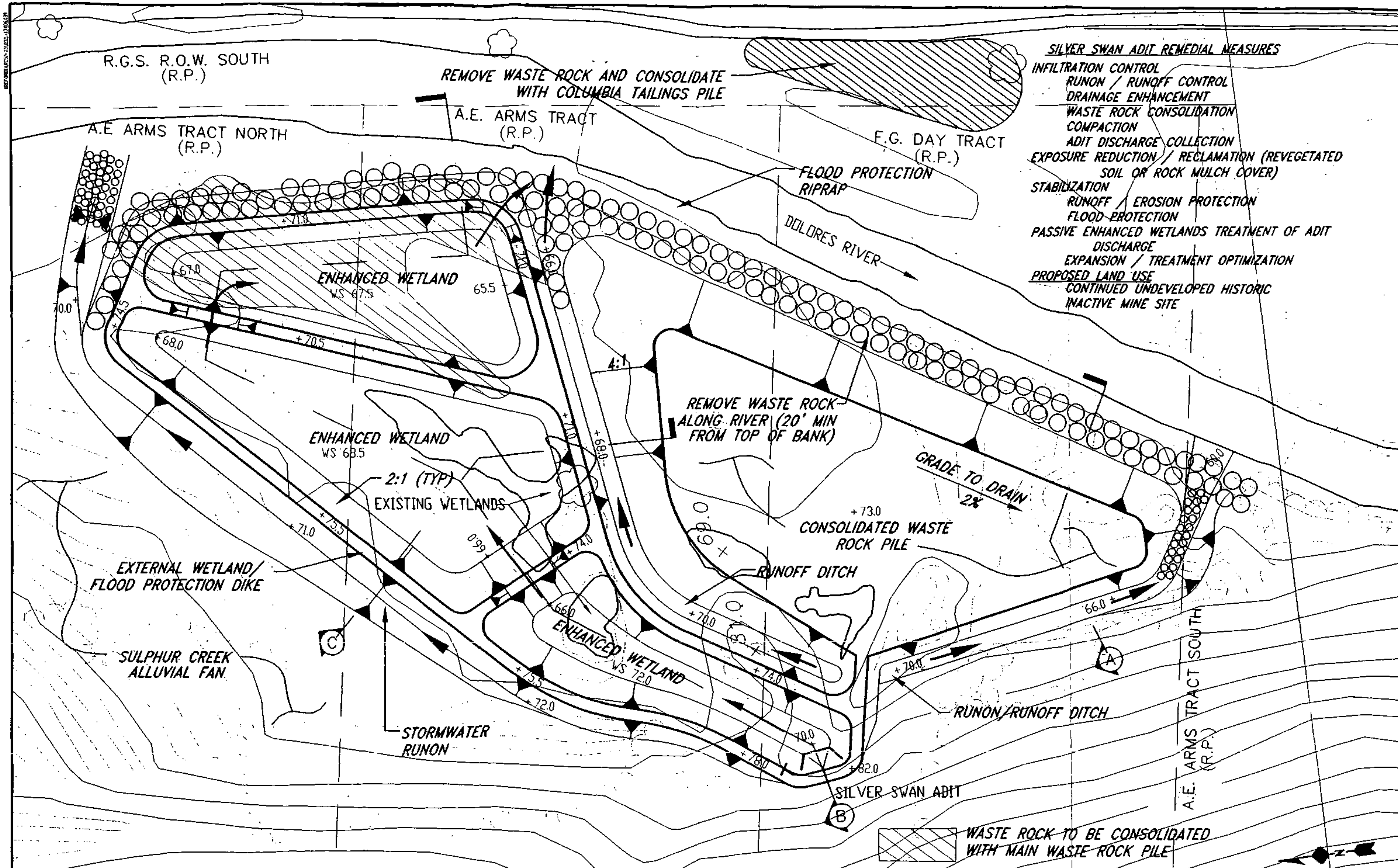
4.3.2.1 Hydrologic Controls

Runon Control. Controls to minimize runon of flows originating off site, as shown schematically on Figures 4-1 and 4-2, involve the following remediation elements:

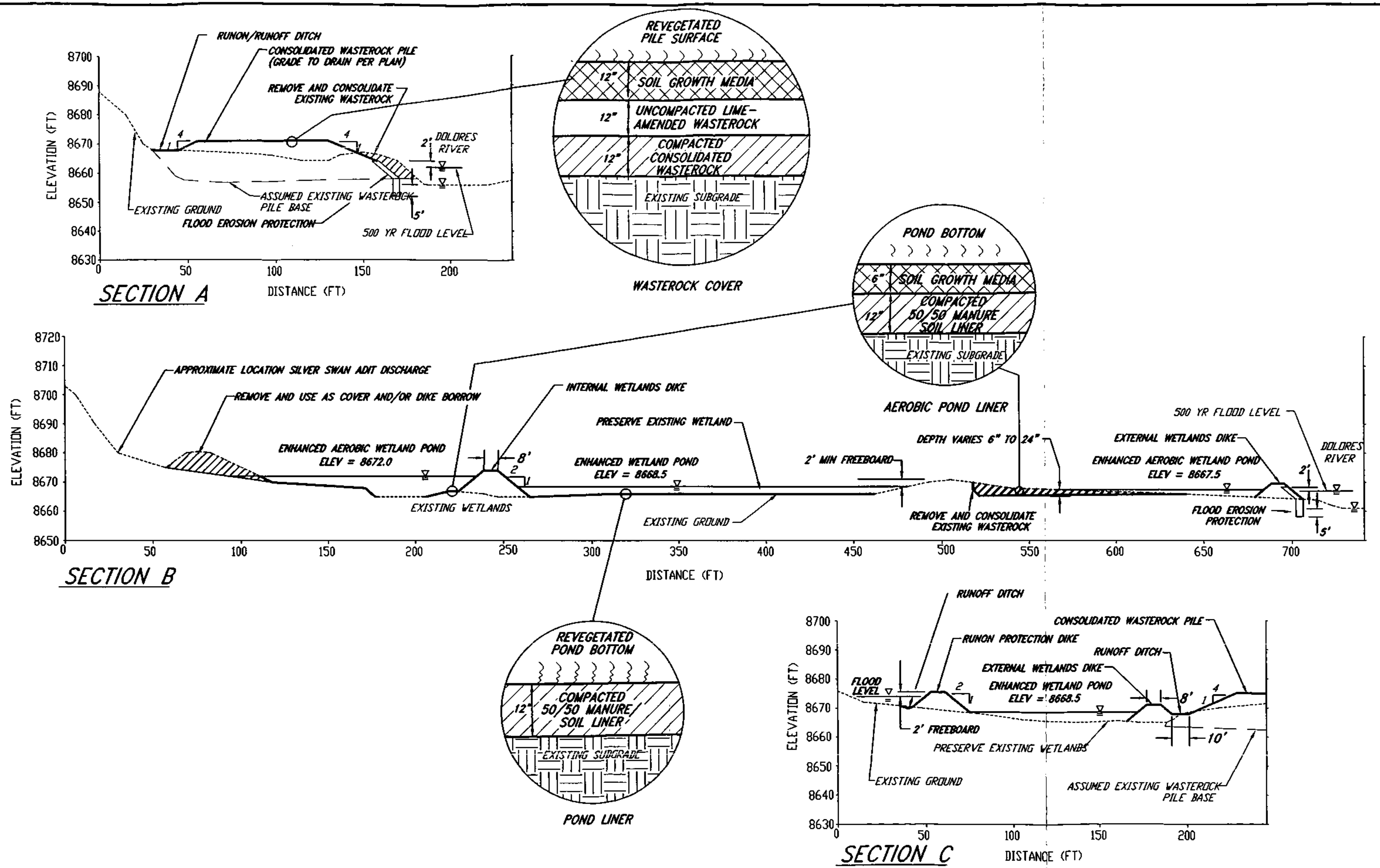
- *Approximately 320 lineal feet of combined runon-runoff ditch around the waste pile; and*

- *Approximately 600 lineal feet of runon swale behind the upslope wetland dike described later.*

Runon will be generated due to precipitation and/or snowmelt from the forested slope immediately above the site. The contributing drainage areas for local runon include approximately 76 acres above the wasterock pile and about 521 acres in the Sulphur Creek drainage above the wetlands treatment area. Peak runon flows from these two subbasins are conservatively estimated as 28 cfs and 101 cfs, respectively, for the 100-year precipitation event (see Appendix C1 for hydrologic calculations). Runon will be split at the adit location, such that a portion will be captured and conveyed in a ditch along the western boundary of the waste pile, and the remainder will be intercepted by an extension of a flood dike protecting the wetlands area occupying the north portion of the site. Conceptual sizing of the required flow cross-sectional area of the ditch bordering the waste pile is on the order of 6 square feet, while the area behind the wetlands dike will be on the order of 30 square feet not including 2 feet of freeboard. The conceptual layout assumes a flowline invert grade of 3 percent for the ditch and 0.5 percent behind the wetland dike, except at the southerly end of the runon ditch and the eastern end of the dike. These grades will result in flow velocities on the order of 4 feet per



SCALE HORIZ: 50 VERT: N/A SCALE IN FEET 0 25 50	REMEDIAL MEASURES SILVER SWAN SITE PLAN	Figure 4-1



SCALE HORIZ: 1"=50' VERT: 1"=20'
SCALE IN FEET 0 25 50

REMEDIAL MEASURES
SILVER SWAN CROSS SECTIONS

Figure 4-2

second (fps) which should not be erosive in the revegetated, relatively coarse-grained alluvial/colluvial soils and/or borrow material anticipated in the dikes/ditches. The runon discharge would drop to the Dolores River in riprap lined (or equivalently protected) channels; a small riprap lined plunge pool would be provided at the discharges if necessary as part of final design.

Runoff Control. Runoff controls, as shown schematically on Figures 4-1 and 4-2, involve the following remediation elements:

- *Reducing potential erosion due to runoff by removing approximately 8000 cubic yards of wasterock in a minimum 20-foot wide buffer zone along the west bank of the Dolores River, and removal of the wasterock on the east bank to the Columbia Tailings Site (estimated as 600 to 1300 cubic yards);*

- *Regrading of the existing wasterock dump to provide a surface sloped to drain at 2 percent and maximum side slopes of 4H:1V; and*

- *Conveyance of runoff flows in swales or ditches at the periphery of the waste pile to the Dolores River.*

The existing wasterock on the west bank of the Dolores River will be excavated and consolidated with the remainder of the waste to be left in place. A buffer zone, a minimum of 20 feet wide, will be formed by excavating to natural ground. This buffer zone, together with the regrading of the waste pile discussed below, will effectively eliminate the potential for erosion and sloughing of wasterock into the river. The smaller wasterock dump on the east side of the Dolores River will be excavated and hauled to the Columbia tailings site where it will be consolidated and remediated with the tailings and other mining and milling wastes from the Pro Patria mill site.

The regraded wasterock pile will occupy an area of approximately 1.3 acres. Peak runoff flow from the remediated wasterock pile for the 100-year precipitation event is estimated as about 3.3 cfs, assuming a runoff coefficient of 0.5 (see Appendix C1 for hydrologic calculations). The 2 percent grades and 4H:1V slopes proposed, together with the additional infiltration control discussed later, will shed runoff from the waste pile. The reclamation cover will prevent the runoff from coming into contact with the water material thereby preventing the water from becoming contaminated before entering the Dolores River. The large majority of the runoff will occur as sheetflow into ditches around the north and west sides of the regraded waste pile. A major portion of the runoff will enter the runon/runoff ditch and flow south to the Dolores River. Some of the runoff will enter the runoff ditch at the north-northwest end of the pile and flow east to the river. The minimal runoff from the east slope of the regraded wasterock pile will flow through the flood protection riprap to the Dolores River.

Infiltration Control. Infiltration controls, as shown schematically on Figures 4-1 and 4-2, involve the following remediation elements:

- *Rerouting adit discharges off of the wasterock pile;*
- *Reducing the total surface area of wasterock at the site;*
- *Regrading of the wasterock surface for runoff drainage as described previously; and*
- *Compaction of the wasterock surface.*

Rerouting the existing adit discharge away from the surface of the wasterock pile is the measure that will have a significant impact on reduction of infiltration over current conditions. The constant infiltration of the majority of the estimated average 50 gpm of adit flow will be effectively eliminated by this measure. As discussed more fully later under Passive Treatment (Section 4.3.2.3), the adit flows will be conveyed directly into the upgradient, lined pond at the head end of the enhanced wetlands system. The proposed compacted organic/soil liner will significantly reduce potential infiltration from this historic source into the adjacent wasterock via the underlying colluvial/alluvial deposits.

The total surface area of wasterock at the site will be reduced about 20 percent, from approximately 1.7 acres to 1.3 acres, by consolidating wasterock from the enhanced wetlands area, removing wasterock from the west river bank, and relocation of the east waste dump to the Columbia tailings site. This reduction will decrease overall infiltration of snowmelt and precipitation through wasterock immediately adjacent to the Dolores River. More importantly, infiltration will be significantly reduced by providing unimpeded runoff of incident precipitation through proper grading of the top surface and slopes of the regraded waste pile.

Compaction of the wasterock immediately underlying the upper approximately 12 inches of lime-amended wasterock (described later under Reclamation Cover) to 95 percent of Standard Proctor (or equivalent maximum index density) is proposed to further inhibit infiltration. Note that the uppermost approximately 12 inches of lime-amended wasterock must not be compacted as it forms the lower half of the reclamation cover seedbed. Based on field observations and experience with similar wasterock types, it is anticipated that the mass grading will result in a workable gradation at the surface to be compacted. Proper moisture control will be required to achieve the required compaction. In this type of material, the density achieved by compaction can reduce hydraulic conductivity, although the decreases associated with compaction alone are anticipated to be substantially less than an order of magnitude. It is likely that the greater effectiveness of the surface grading and compaction efforts would be associated with the mixing of the soils and breakdown of some of the larger fragments under the equipment loads. It is anticipated that these mechanisms will tend toward a more well-graded particle distribution, and thereby lower hydraulic conductivity.

If necessary, locally, one or more additional measures could be employed to avoid any significant areas of open-work wasterock at the compacted surface. Such measures might include: blending of coarser material pockets with adjacent finer materials; use of heavier or different type of equipment to disaggregate rock fragments (e.g., sheepsfoot versus vibratory smooth drum); and/or local addition of sandy to silty soils. In addition to the required compaction of the near surface to 95 percent of Standard Proctor, nominal compaction of any underlying waste materials disturbed during regrading would be specified. This would include specifying maximum loose placement depths and minimum passes with appropriate tracked or wheeled equipment.

Drainage Stabilization. The Site is located adjacent to the Dolores River and at the periphery of the alluvial fan of Sulphur Creek. The remediated wasterock pile and enhanced wetland area will be protected from flood flows and resultant erosion by the following remedial measures (Figures 4-1 and 4-2):

- *Slope and toe erosion protection of the periphery of the wasterock pile extending approximately 440 lineal feet along the west bank of the Dolores River;*
- *Approximately 800 lineal feet of earthfill dike around the portion of the periphery of the enhanced wetlands area susceptible to flooding (i.e., external wetlands dike); and*
- *Riprap (or equivalent) slope and toe erosion protection for the external wetlands dike.*

The remediated wasterock pile will be protected from 500-year discharges in the Dolores River (see Appendix C1) by riprap of adequate height to contain the flood stage with 2 feet of freeboard. Preliminary estimates indicate this will require riprap on the order of 10 to 12 feet above estimated original ground at the river bank. Anticipated high velocity flows during the peak of the design event (on the order of 15 to 20 fps) will require substantial erosion protection. Given the potential scarcity of sufficiently large size riprap in the immediate area, options including gabions, grouted riprap or other methods will be considered during final design. The enhanced wetland area will be protected from at least 100-year flood flows, including provision of 2 feet of freeboard and protection against scour of the slopes and toe of the external dike along the Dolores River. In fact, it is anticipated that 500-year protection will be provided along the wetlands dike as a cost-effective alternative to such protection along the north periphery of the remediated waste pile. Freeboard and erosion protection will also be provided along the toe of the Sulphur Creek alluvial fan where the dike is subject to the potential of 100-year flows utilizing this portion of the fan (flows already accommodated in the runon estimates discussed previously). The external wetlands dike height will be governed by the higher of the external flood stage plus a 2-foot freeboard or the internal wetland pool flood elevation plus wave runup freeboard, as established during final design. If found necessary during final design, local reaches of the external dike traversing wetlands areas would be constructed on appropriately specified geotextile to ensure constructability and minimize fill requirements.

4.3.2.2 Reclamation Cover

The preferred alternative for reclamation cover at the Silver Swan Mine site involves the following remedial measures, as illustrated schematically on Figure 4-2:

- *Lime amendment of the upper 12 inches of wasterock;*
- *Placement of 12 inches of colluvial soils (approximately 1600 cubic yards) as additional growth media over the amended wasterock surface;*
- *Revegetation of the regraded wasterock pile (approximately 1.3 acres); and*
- *Revegetation of disturbed native soils and new dikes/ditches (approximately 0.4 acres).*

A comprehensive discussion of site soil characteristics and their revegetation potential is presented in a soil characteristics report and recommended revegetation plan prepared by Cedar Creek Associates (1995a and 1995b; provided with application under separate cover). Key elements of this preliminary plan applicable to the Silver Swan Mine site are summarized in the following paragraphs.

The surface reclamation concept for the remediated wasterock pile at the Silver Swan site is to provide a suitable growth medium approximately 2 feet deep by lime amending the upper approximately 12 inches of the wasterock, placing an additional 12 inches of borrow soil, and then revegetating. In addition to providing a suitable lower seedbed, the amended wasterock section will tend to mitigate potential upward migration of metals and/or acidic moisture due to capillarity or diffusion. Required lime application rates will be established by sampling of the final water surface materials during reclamation. Lime will be incorporated in the wasterock by tilling.

The source of borrow soil for the upper 12 inches of growth media assumed for conceptual layout and design purposes is the existing disturbed borrow area in the slope above the St. Louis ponds system, approximately 2 road miles north of the site. Although containing what would typically be considered somewhat high percentages of coarse fragments, this borrow material appears otherwise suitable as growth media based on its pH, conductivity and low metals concentrations. In this application, the higher percentage of rock fragments will provide supplemental erosion resistance, as long as the fragments are not so large or numerous as to inhibit establishment of the vegetative cover. Existing piles of colluvial spoil near the adit will be used for a small portion of the required borrow. The potential to utilize alluvial fan and/or alluvial soils present within and immediately adjacent to the enhanced wetlands area as the major source of borrow soil would be considered during final design. If these materials are of suitable gradation or can be readily screened on-site, and if borrow excavations can be kept largely within areas to be submerged, this source may be preferable to the St. Louis borrow site.

The general seed mix proposed for the wasterock pile emphasizes native grass species, and includes slender and streambank wheatgrasses to address erosional stability of reclaimed surfaces. Other species are included based on their establishment potentials and to increase native species diversity (i.e., big bluegrass and mountain brome). In addition to the grasses, four forb species are proposed (Rocky Mountain penstemon, birdsfoot trefoil, cicer milkvetch and Lewis flax) based on their adaptive characteristics and positive aesthetic appeal. The mixture proposed for sideslopes on dikes and ditches where riprap or other high erosion resistance materials are not required, is simplified from the general mix. Species which do not add to the stabilization objective, and which might compete with more desirable species for available soil moisture and nutrients are excluded.

Samples of the prepared seedbed will be taken during reclamation to establish appropriate types and application rates of fertilizer. Fertilizer will be broadcast over the seedbed and incorporated by discing. The appropriate seed mix will then be broadcast and the surface slightly roughened to cover the seed. The seeded area will be mulched at a rate of 2 tons/acre following seeding with the mulch anchored by crimping.

An alternative reclamation cover under consideration for the Silver Swan site is non-vegetated rock mulch. Rock mulch is defined herein as soils consisting predominantly of rock fragments (gravel sizes or larger) with sufficiently low sand and fines content so that the rock fragments effectively control the erosion resistance of the cover. An acceptable range of gradations will be established as part of final design to specify this material. The currently assumed source of rock mulch is the St. Louis borrow tunnel area. At least one pass through a screening operation is anticipated to develop rock mulch from the colluvial soils. A thorough coverage of 2 inches minimum thickness will provide adequate erosion resistance on the graded surfaces and shallow slopes of the regraded wasterock pile. A minimum of four inches would be specified to accommodate the variability anticipated with standard placement techniques, thereby assuring that the 2-inch standard is achieved. These proposed thicknesses are based on the assumption that the reclaimed areas will not be subject to vehicular traffic or other man-induced disturbances that could disrupt the cover, and that slopes are no steeper than 4H:1V. This alternative is being carried forward in the event that the actual characteristics and/or quantities of borrow at the St. Louis site dictate minimizing required volumes of fill from that source at this and/or the other sites. The rock mulch alternative would require approximately 1100 cubic yards versus the 1600 cubic yards of soil for the preferred alternative described above. Lime amendment of the near surface wasterock would not be necessary with the rock mulch alternative.

Can you incorporate the existing wetlands into treatment system? Brad Miller

Permit - Discharge

4.3.2.3 Passive Treatment of Mine Drainage

Passive treatment of the Silver Swan Mine adit discharges is proposed in an enhanced wetlands area at the north end of the site (Figure 4-1). The conceptual sizing of the wetlands is based on utilization of the largest reasonably available area at the site. This area has been selected based on consideration of a number of factors, including:

- Reported ranges of wetlands area versus inflow rates for successful systems of generally similar type;
- Utilization of the existing lower ground between the Sulphur Creek alluvial fan and the Silver Swan Mine waste dump;
- Keeping the ponded water isolated from the waste pile; and
- Minimizing unnecessary disturbance of the alluvial fan.

The wetlands treatment concept proposed for the Site relies on a variety of anticipated mechanisms to attenuate metals in the adit discharges to a significantly greater degree than is provided by the existing small wetlands on the waste dump. The primary mechanisms envisioned are aeration, filtration, adsorption, plant uptake, aerobic and/or anaerobic (microbially mediated) precipitation, and sedimentation. The intent is to construct a system within which these various mechanisms will be present and/or develop naturally over time.

The shallow *flow over soil type* wetlands system proposed will provide an effective treatment area totaling approximately 0.9 acres. The U.S. Bureau of Mines (BOM) and Tennessee Valley Authority (TVA) experience with natural and constructed wetlands treatment of mine drainage indicates that on the order of 20 to 45 kg/day of iron can be treated per acre of wetland (or 5 to 11 g/day per m^2 in the units used by BOM and TVA) for flows with pH >4, and iron concentrations less than 50 mg/l. Silver Swan adit discharge pH and iron concentrations are expected to be well within the indicated ranges. Assuming the estimated average inflow rate of 51 gpm, and maximum iron content of 10.3 mg/l, the iron loading is about 3 kg/day. Thus, the total 0.9 acre system is significantly oversized. Wetlands sizing calculations are discussed in more detail in a report by Pintail Systems and Schafer and Associates (PSI and SA, 1995) provided with this application under separate cover.

The conceptual enhanced wetlands layout provides for an aerobic treatment step in an upgradient pond to enable oxidation precipitation of dissolved iron and to serve as a sludge storage pond. Available adit water quality data suggest that sludge generation rates will likely be low, but an aerobic step is considered prudent given the apparent effectiveness of the existing conditions in decreasing iron and some other metals in flows from the adit to the small wetlands on the waste dump (see Appendix C3 for wetlands sludge generation calculations). This presumption is based on the sampling results described previously in Section 2.6.2. The aerobic pond is conceptually sized as about 0.18 acre surface area, with water depths on the order of 2 to 6 feet and a retention time of 3.2 days. Adit flows would enter the upper end of this pond just below the current area of discharge to maximize use of the reasonably available area. The aerobic pond is estimated to provide sufficient volume to hold accumulated sludge for a period of between 23 and 77 years based on compacted sludge concentration ranging between 3 and 10 percent.

The central part of the enhanced wetlands system would consist of one or more cells in an area of approximately 0.46 acres impounding water with depths ranging from about 6 inches to 3.5 feet. The shallow wetlands pond(s) would be lined sufficiently to contain most of the adit flows for treatment. Any lining which results in surface ponding and treated discharge to the river would also result in a lower total flux of seepage beneath the downgradient waste pile to something less than has occurred historically. The conceptual alternative for the liner is a compacted, manure-amended soil layer one foot thick. A mix of approximately 50 percent manure and 50 percent soil (volume basis) is envisioned. The hydraulic conductivity of such a liner mix would be verified during final design using the proposed borrow soils and manure from sources to be identified in the general vicinity. If the necessary hydraulic conductivity cannot be feasibly achieved with a soil/manure liner using available soils, use of more thoroughly processed and/or bentonite amended soils would be considered during final design. An advantage of the soil/organic liner concept is that it would also provide some measure of treatment to the envisioned minor seepage flux through it, and serve as a substrate for establishment of wetlands vegetation.

A second aerobic pond is planned at the downgradient end of the wetlands. This pond would mitigate the dissolved oxygen deficiency anticipated due to the oxygen demand of the central pond(s) containing an anaerobic substrate and would treat dissolved manganese. This pond is conceptually sized as approximately 0.26 acres, ranging from six inches to two feet in depth.

A compacted soil/organic liner as described above is also envisioned for the aerobic ponds at the up- and downgradient ends of the system, except that an additional cover of 6 inches of soil without manure amendments would be placed over the 12-inch liner. The cover soil will maintain a more aerobic condition which is conducive to iron and associated metals precipitation in the uppermost pond, and to increasing dissolved oxygen levels and precipitation of manganese in the lowermost pond.

The soil liner/substrate in all of the wetland cells would be placed to provide an undulating microtopography conducive to diverse habitat conditions for the plants and microbial organisms essential to the overall treatment mechanisms desired. Selected wetlands species from local natural wetlands would be transplanted to the substrate/liner in each of the cells described previously. This measure, and the proposed manure additions as part of the soil liner, will initiate the natural development of the biologic component of the enhanced wetlands system.

4.4 Operations and Maintenance Plan and Monitoring

The VCUP should include: *"A remediation system operation and maintenance plan that describes, at a minimum, how the system will be operated to ensure that it functions as designed without interruptions and a sampling program that will be used to monitor its effectiveness in achieving the desired goal."*

4.4.1 Operations and Maintenance Plan

The proposed VCUP for the site is intentionally comprised of remedial measures requiring the minimum practicable operations and maintenance and maximum practicable service life consistent with the applicable performance objectives, regulatory requirements, and anticipated future land uses. An overview of the anticipated O&M for the major elements of the proposed remedy is presented here. The specific requirements for operation and maintenance will be refined as part of final design before implementation of the remediation.

No specific operations are required for the hydrologic control, slope stabilization or reclamation cover elements of the VCUP. The need for maintenance of these elements is also expected to be minimal, assuming that they are not subjected to loadings or disturbances for which they are not designed. An annual inspection is proposed for the first five years after construction of the remedy to verify that the integrity of these measures has not been breached and/or to identify any conditions requiring maintenance (e.g., local disturbance of rock mulch cover or channel erosion protection). Additionally, an inspection should be made following severe precipitation events or earthquakes approaching the design basis events.

Hydraulic and treatment operation of the passive wetlands treatment system does not require operator attention on a routine basis. Flows are by gravity and control structures are simple overflows at set elevations. Treatment processes occur by natural mechanisms as discussed previously. Appropriate flexibility is included to adjust overflow elevations (and thereby flow rates and pond levels) if necessary and appropriate for operational or maintenance reasons. It is proposed that system operation be appropriately monitored and refined during the first year after construction. This will include observation of hydraulic function and sampling and analysis of treatment performance under an annual range of inflow and climatic conditions. The frequency and scope of subsequent operational requirements would be established based on the results of the first year's monitoring.

4.4.2 Monitoring Plan

A program to confirm the effectiveness of the VCUP will include:

- Pre-VCUP water quality determination
- Post-VCUP confirmation sampling

- Assessment of enhanced wetlands performance

4.4.2.1 Pre-VCUP Water Quality Determination

A pre-construction water quality sampling program will be conducted to further determine water quality sampling of adit, wasterock and wetland discharges. Water quality will be determined from existing information and additional samples collected prior to construction. Results of the water quality program will be used to determine final design of the enhanced wetland system and for the comparative assessment of post-VCUP system performance.

The water quality sampling program will be implemented in the fall of 1995, continue until start of construction, and include the following sampling station locations, parameters, and frequency of sampling:

1. **Sampling Locations**

   Silver Swan adit
   Seepage points (mine waste pile)
   Wetland inflow
   Wetland outflow

2. **Parameters**

Field	Laboratory
Flow rate	Total-recoverable and dissolved:
	Iron
pH	Manganese
Temperature	Cadmium
Specific conductance	Copper
Eh	Lead
Total iron and dissolved iron (II)	Silver
Dissolved oxygen	Zinc
Alkalinity	Total suspended solids
	Total dissolved solids
	Hardness
	Sulfate

All sampling will be performed according to specified methods in 40 CFR, Part 136; methods approved by EPA pursuant to 40 CFR, Part 136; or methods approved by the Division, in the absence of a method specified in or approved pursuant to 40 CFR, Part 136. The analytical method selected for a parameter will be the one that can measure the lowest detected limit for the parameter unless the stream standard for that parameter is within the testing range of another approved method.

3. **Frequency**

Quarterly (weather and access conditions permitting)

4.4.2.2 Post-VCUP Confirmation Sampling and Inspections

A post-VCUP confirmation sampling and inspection program will be conducted to determine the performance of the enhanced wetlands passive treatment system and its effectiveness in reducing mine drainage metal concentrations as compared with pre-VCUP water quality. Qualified personnel will conduct inspections concurrent with sampling events. Such personnel will inspect all control measures identified in the VCUP to ensure that they are operating as designed. Results of each inspection and sampling event will be summarized in a written report, including scope of the inspection/sampling, personnel, date of inspection/sampling, major observations, any actions taken as a result of the inspection and/or sampling, and sampling results.

The confirmation program will be conducted for one year following completion of construction and include the following sampling station locations, parameters and frequency of sampling:

1. **Sampling Locations**

   Silver Swan adit
   Wetland outfall

2. **Parameters**

   Same as pre-VCUP program

3. **Frequency**

   Daily for first week (field parameters)

   End of first week (all parameters)

   Quarterly thereafter (all parameters; weather and access conditions permitting)

4.4.2.3 Performance Assessment, Records and Reporting

An assessment of inspection and confirmation sampling results will be performed to determine effectiveness of control measures in reducing metals loading and improving water quality. The assessment will take into account pre-VCUP and post-VCUP water quality information for the Site, historic Dolores River water quality upstream and downstream of the site, and numeric water quality standards for Dolores River (Segment 3) effective May 30, 1995. Records of all assessment, inspection and monitoring information will be established and maintained by the applicants. Such information will be submitted to the Division. These reports will include conclusions, major observations, results of sampling, site inspections reports and any follow-up activities, and assessment of the VCUP's effectiveness.

4.5 Management of Wastes Prior to Implementation of Remedial Action

"The plan should describe how the waste, or contaminated media will be managed prior to treatment, and/or disposal."

The remedial alternative does not include treatment or removal and disposal at an offsite location. There is no formal management of the site. The site lies on private property.

4.6 Hazardous Waste Generation

"The plan should discuss whether or not a hazardous waste will be generated by its implementation (e.g. through the excavation of contamination, which may have been discharged prior to 1980, but which would become a hazardous waste upon being dug up or managed), and the volume of this material. The plan should also describe how such hazardous waste will be managed in accordance with current state and federal hazardous waste regulations."

No hazardous waste will be generated by implementation of the VCUP.

4.7 Verification Sampling Program (Wasterock)

"If applicable, the plan should describe the sampling program that will be used to verify that treatment of the contaminated media has resulted in a non-hazardous waste."

The proposed remedial alternatives for the site does not include the treatment of the wasterock materials. Therefore, a verification sampling program for the wasterock is not applicable.

4.8 Remediation Risk Analysis

No significant short- or long-term risks have been identified for the remediation proposed in this VCUP. Short-term (implementation/construction period) risks will be typical of those for any earthmoving project, and are readily manageable so as to effectively avoid any significant environmental or health and safety consequences. As discussed in Section 4.3.1, construction controls will be fully implemented to protect the Dolores River, and undisturbed lands adjacent to the work areas and/or offsite from uncontrolled releases of sediment or mine waste. The technologies to be employed for the proposed remediation, and the construction control BMPs are simple, have been used successfully for decades, and are readily controlled and verified by on-site inspection and supervision of the work.

All on-site construction and related activities will be conducted in strict conformance with a Site Specific Safety and Health Plan to be developed prior to mobilization. A Site Safety Officer will be designated to ensure that the requirements of the plan are met, and that safe work practices are implemented. Preliminary personal air monitoring and experience at other similar sites suggests that health risks will be minimal during earthmoving operations using appropriate BMPs.

Potential long-term risks to the integrity of the proposed remediation at the site include natural processes or hazards such as erosion, floods and earthquakes, and man-induced disturbances such as inappropriate land use. The design of the various elements of the remediation to the standards identified in Section 4.2 and as described in Section 4.3 will effectively mitigate the potential for significant damage and/or release of contaminants from the sites under the design events adopted (e.g., 100-year/500-year flood; design basis earthquakes). Design, construction and operation of the earthwork and hydraulic structures and facilities comprising most of the remediation to these types of standards (and in fact to much more stringent standards for critical facilities) have been demonstrated to be readily achievable and effective on innumerable projects of similar scope and conditions. The potential for man-induced disturbances is effectively addressed by land use and related institutional controls as described in Sections 4.2.6 and 4.9.

The technical and economic feasibility of the proposed remediation at the site derives from the nature, scope and relative simplicity of the design and implementation of the plan as discussed above. Compared to all other elements of the remediation, the wetlands treatment systems have relatively fewer directly applicable pilot and/or full-scale precedents on which to draw. However, even this aspect of the project is judged economically and technically feasible in the context of the appropriate application of innovative technology at the site.

4.9 Land Use/Institutional Controls

The proposed land use for the site will be as a continued inactive mine waste site with potential use as open space as part of a river corridor. Maintenance for the use will largely be self-implementing. ARCO and the current landowner Applicant will work to ensure continued coordination and site maintenance. Some of the mechanisms currently being evaluated for the private parcel, include application of Rico planning and development regulations, dedication of land parcels to town ownership, use easements, restrictive covenants, and conservation easements. Specific mechanisms to be employed for the site will be determined and executed as part of VCUP implementation.

4.10 Permit Requirements

The plan should identify all permits (Federal, state and/or local including, if necessary, EPA Form 8700-12-Notification of Hazardous Waste Activity, required on the generation of hazardous waste) that will be needed before the plan can be implemented.

Three general areas involving permitting or government approval issues have been identified:

1. Water Quality - Passive Mine Drainage. The passive filtration wetlands system and related water quality improvement components of the project will be developed with appropriate input and/or approval from the Water Quality Control Division ("Division") of the Colorado Department of Public Health and Environment ("CDPHE"). The applicants are currently coordinating with the Division to determine the appropriate mechanism for obtaining such input or approval. Options include: (i) the use of a short-term, general or individual permit under the NPDES program tailored to specific reclamation projects; (ii) approval under the State's non-point source control regulations for passive treatment of mine drainage, 5 C.C.R. § 1002-22; (iii) applying substantive state standards through the ARARs program but waiving actual permit requirements under § 121(e)(1) of CERCLA based on the "removal or remedial" nature of the project; and (iv) application of the "Good Samaritan" provision in pending Clean Water Act reauthorization legislation specifically allowing for voluntary remediation of historic, abandoned mine drainage without full NPDES permit. Regardless of the final permitting approach taken, the VCUP will take into account specific surface water quality standards in place for the appropriate segments of the Dolores River and its tributaries, as discussed above, in establishing discharge goals for the system.

2. Dredge and Fill Permit. All fill work performed within the existing wetlands will comport with appropriate U.S. Army Corps of Engineers ("Corps") and EPA standards. Formal approval will likely come through the Corps' nationwide permit system under Section 404 of the Clean Water Act. ARCO continues to explore the availability of a permit waiver under Section 121(e)(2) of CERCLA applicable to response actions of the nature being undertaken here. In any case, best management practices associated with construction activities within wetlands will be employed.

3. Reclamation Standards. While no reclamation permit will be required from the Colorado Mine Land Reclamation Division ("MLD") or other agencies, the applicants will

consider and apply appropriate MLD standards to those aspects of the project involving traditional reclamation activities.

4.11 Schedule of Implementation

The plan should include a schedule of implementation.

Implementation of remediation for the Silver Swan site will begin immediately upon approval of the VCUP. The major required activities in their general order of implementation are:

- Final design engineering and preparation of construction documents
- Permitting
- Project procurement (bidding, negotiation, award)
- Construction

As appropriate, certain of these activities and/or specific sub-activities would be performed with overlap or concurrently. It is anticipated that engineering through review should be achievable within six months of the start date. Project procurement can be completed in no more than three months. These activities generally are not seasonally (weather) dependent, with the exception of final design field investigations and site surveying. Construction, on the other hand, is highly dependent on weather and river flow as discussed below.

The construction season at the site is reasonably assumed as from May 15 to October 15. A variation of plus or minus two to three weeks on both ends of these construction seasons is probable. The duration of construction activities is estimated at 2 months.

The total duration of the project is strongly influenced not only by the durations of various tasks, but also the start dates of seasonally dependent activities. If, for example, final design investigations and site surveys cannot begin before weather sets in the late fall, then design and preparation of construction documents would be delayed until the following summer. Similarly, if pre-construction activities delay the potential start of construction until too late in the summer, it may be necessary to delay work until the following spring or summer. In general, the construction would not be split between two seasons due to potential damage to uncompleted parts of the work, greater risk of offsite sediment releases, and higher costs associated with winterization, remobilization and repair of any damaged work.

Given the factors and conditions discussed above, the required 24 month time limit for implementation of the remedial measures at the Rico site can be met, assuming the following conditions are met:

- Any necessary permits are attained in a reasonably timely manner (within no more than 6 months from initial submittal of permit applications);

- The construction seasons identified above are not significantly impacted by extremely severe weather;

- Any necessary reviews of construction drawings and technical specifications are performed in a timely manner (within no more than 6 months from initial submittal for review); and

- Seasonally dependent activities are not delayed into the following year.

4.12 References

Cedar Creek. 1995a. Characterization of soil/solid waste for proposed voluntary remediation of mining-related disturbances in Rico, Colorado. Report prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants Inc., Fort Collins, Colorado. Cedar Creek Associates, Inc., Fort Collins, Colorado. September.

Cedar Creek. 1995b. Revegetation plan for proposed voluntary remediation of mining-related disturbances in Rico, Colorado. Prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants, Inc., Fort Collins, Colorado. Cedar Creek Associates, Inc., Fort Collins, Colorado. September.

Colorado Mined Land Reclamation Division. 1988. Appendix C, Recommended Best Management Practices for Abandoned and Inactive Mining; in Water Quality Management Practices for Non-Point Source Pollution Related to Mine Waste and Mine Drainage; November.

Idaho Department of Lands. 1992. Manual of Best Management Practices for the Mining Industry in Idaho. November.

PSI and SA. November 1995. Rico mine district wetland evaluation, Santa Cruz mine area, Silver Swan mine area, Argentine tailings site. Report prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants Inc., Fort Collins, Colorado. Pintail Systems, Inc., Aurora, Colorado and Schafer and Associates Denver, LLC., Lakewood, Colorado. November.

State of Colorado, Division of Minerals and Geology. 1995. Mineral Rules and Regulations of the Colorado Mined Land Reclamation Board. Effective May 1977. Amended January 1995.

APPENDIX A

QUALIFICATIONS OF PREPARERS OF VOLUNTARY CLEANUP APPLICATION

Qualifications of Preparers of Voluntary Cleanup Application

The Atlantic Richfield Company selected a multi-disciplinary Team of qualified environmental and engineering professionals assembled by ESA Consultants Inc. to prepare the Voluntary Cleanup and Redevelopment Act application for the site. The Team includes key environmental and engineering professionals from several environmental consulting firms as follows:

ESA Consultants Inc., Fort Collins, Colorado (Lead Firm)

W. Roger Hail, C.E.G.	Project Principal
Edmund J. Schneider, P.G.	Project Manager
Douglas M. Yadon, P.E.	Project Engineer
William R. Kelly, P.E.	Civil Engineer (Hydraulics/Water Treatment)

Cedar Creek Associates, Inc., Fort Collins, Colorado

Stephen G. Long	Site Assessment/Reclamation
Steven R. Viert	Site Assessment/Vegetation and Wildlife Habitat

Environmental Management Systems Company, Fort Collins, Colorado

Thomas E. Gast	Site Assessment/Operational History

Pintail Systems Inc., Aurora, Colorado

Leslie C. Thompson	Site Assessment/Wetlands/Bioremediation

Planera, Inc., Fort Collins, Colorado

Bernhard E. Strom	Site Assessment/Land Use

PTI Environmental Services, Boulder, Colorado and Bellevue, Washington

Michael V. Ruby	Site Assessment/Water Quality
Rosalind A. Schoof, Ph.D.	Health Risk Assessment
Yvette Wieder Lowney, M.P.H.	Health Risk Assessment

Schafer and Associates Denver, L.L.C., Lakewood, Colorado

Lorraine H. Filipek, Ph.D.	Site Assessment/Geochemistry

A company profile and summary of environmental engineering capabilities for ESA Consultants Inc. and resumes of key Team personnel are provided in the following sections.

ESA CONSULTANTS INC.
COMPANY PROFILE AND ENVIRONMENTAL ENGINEERING CAPABILITIES

COMPANY PROFILE

ESA Consultants Inc. (ESA), was founded in 1969. Since that time we have developed the engineering resources, project management capabilities and technical expertise to provide our clients with the best and most appropriate technologies for environmental protection, water resources development and management, and mining industry support.

ESA has been engaged in Superfund work since 1982 and has the capabilities and experience to support projects from the initial site assessments through implementation of selected remedies. Since 1988 the majority of ESA's Superfund work and emphasis has been the performance of Expedited Response Actions and Remedial Designs/Remedial Actions. We specialize in detailed site assessments for design support, preliminary and final designs, cost estimating, plans and specifications, bid documents, construction oversight, negotiations support, and other matters related to implementation of remedial actions.

The firm's environmental project experience also includes siting studies, permitting, environmental impact statements/reports, litigation support, design, and other matters related to mining, energy, solid waste, and waste-water facilities. In addition, development and management of surface and ground-water resources has been an integral part of the firm's work since 1969. Water resources and mine related work are complementary to environmental engineering in requiring most of the same staff disciplines and technologies.

Clients of ESA include industry, water agencies, utilities and law firms and ESA has provided services throughout the United States and several foreign countries. ESA is an employee owned business and an equal opportunity employer providing services in the following disciplines.

- Civil Engineering
- Geotechnical Engineering
- Hydrogeology
- Hydrology
- Environmental Engineering
- Hydraulic Engineering
- Geochemistry
- Computer Science

ENVIRONMENTAL ENGINEERING CAPABILITIES

SITE ASSESSMENTS

ESA provides multi-disciplined teams to perform environmental site assessments ranging in complexity from preliminary characterization studies to comprehensive evaluations for remedial design. This is accomplished through appropriate technical investigations and information management:

- **Site reconnaissance and exploration**
  - — Soil and geologic mapping
  - — Land uses and cultural resources
  - — Soil and rock borings and pit excavations

- **Soil and water studies**
  - — Sampling and analysis
  - — Chemical equilibrium modeling
  - — Geochemical modeling
  - — Limnological modeling

- **Ground-water investigations**
  - — Aquifer tests
  - — Flow system modeling
  - — Water quality monitoring
  - — Solute transport modeling

- **Surface-water investigations**
  - — Hydrologic and hydraulic studies
  - — Flood flow determinations
  - — Flood routing
  - — Water quality monitoring

- **Feasibility studies**
  - — Technology screening
  - — Development/screening of initial alternatives
  - — Detailed analysis of alternatives

- **Information and data management**
  - — Data management systems
  - — Quality assurance/quality control plans
  - — Data quality assessment and validation
  - — Documentation review

ENVIRONMENTAL ENGINEERING CAPABILITIES

ENGINEERING DESIGN AND COST ESTIMATES

ESA specializes in the development of detailed designs, construction plans and specifications, and bid documents for Superfund site remedial actions, and RCRA and mine/mill waste facilities. The firm provides engineering design and cost estimates for:

- **Removal actions**

- **Disturbed stream/wetlands systems restoration**

- **In situ waste containment/treatment systems**
  - Slurry walls
  - Multi-media caps and liners
  - Embankments
  - Waste consolidation
  - Wet-closure treatment systems

- **Solid and liquid waste facilities**
  - Liner and seepage collection systems
  - Impoundment embankments
  - Mine waste piles
  - Ground-water monitoring networks

- **Water/waste-water treatment facilities**
  - Settling ponds
  - Pumping systems
  - Chemical feed
  - Clarification
  - Sludge handling

- **Ground-water systems**
  - Supply wells
  - Extraction well systems
  - Treated water injection well systems
  - Interception/drain systems

- **Facility flood protection**
  - Levees/embankments
  - Riprap and soil-cement slope protection
  - Hydraulic structures
  - Sedimentation ponds

KEY PERSONNEL QUALIFICATIONS

- ESA Consultants Inc. (ESA)
- Cedar Creek Associates
- Environmental Management Services (EMS)
- Pintail Systems
- Planera
- PTI Environmental Services (PTI)
- Schafer & Associates

ESA Consultants Inc. (ESA)

W. ROGER HAIL, C.E.G.
Senior Vice President/Division Manager
Principal Hydrogeologist

Academic Credentials
B.S. Geological Engineering, University of Nevada,
Mackay School of Mines, 1956

Professional Licenses
Registered Geologist/ Certified Engineering Geologist - California
Professional Geologist - Wyoming
OSHA Health/Safety Training for Hazardous Waste Operations - 40-hr Certification

Key Qualifications

Mr. Hail has over 37 years of varied experience in the fields of hydrogeology and engineering geology applied to environmental remediation, water resources development and management and mine permitting and development. He acts as Principal-In-Charge, Project Manager or Senior Consultant in his specialty discipline of hydrogeology. His extensive experience has enabled him to stimulate project teams to innovative project approaches and solutions.

Throughout his career, he has worked on projects involving water quality and water quality control for both surface and ground water. Initially, this work was in the water resources field starting with his employment with the California Department of Water Resources and progressing to the consulting field in 1963. Environmental hydrogeology became progressively more important and was applied to mine permitting and design of water quality control measures through the 1970's. With the advent of RCRA and CERCLA, he has been active with project assignments ranging from environmental site assessments, scoping remedial investigation/ feasibility studies and performing remedial design/remedial actions. This work included development of RCRA monitoring systems for four petroleum refineries and a detailed environmental impact assessment for a refinery conversion to synfuels production. An integral part of his work has been interfacing with regulatory agencies including negotiation support, commenting on and responding to comments on various project documents.

Relevant Related Experience

- *Warm Springs Ponds Operable Units, Butte/Silver Bow Creek Superfund Site, Montana.* Mr. Hail has served ARCO as Principal-In-Charge of ESA work ranging from feasibility studies to remedial design/remedial action including negotiation support. He led a team of professionals in developing the ARCO Plan for remediation in parallel to the State's Feasibility Study and helped ARCO to successfully sell this plan in opposition to much more costly alternatives.

- *Other ARCO Service.* Mr. Hail has served Anaconda Minerals Company and ARCO since 1974 on projects in California, Colorado, Montana, Nevada and Utah. He developed mine water and tailings management plans for the Carr Fork Mine in Utah and developed well field operation plans at the Nevada Moly Project. He supported ARCO in negotiating work plans for the Anaconda Smelter NPL Site remedial investigation. He performed a critical review of the RI for the Milltown Dam NPL Site in Montana.

- *Rio Tinto Mine Site, Nevada.* A confidential non-intrusive environmental site assessment was performed for an abandoned mine in Northern Nevada. The site assessment involved review of historic data and reports, aerial photos, topographic maps pertaining to the site and a site inspection. The work included development of remediation concepts and cost estimates to alleviate surface water quality degradation. Also, a critical review was performed of a conceptual design report for remedial measures prepared for other previous owners of the mine site.

- *Summitville Superfund Site, Colorado.* An environmental site assessment was performed for a PRP that included review of extensive documents, maps and aerial photos and a site reconnaissance. The abandoned mine involved extensive underground workings with newer open pit mining superimposed resulting in severe acid mine drainage. Potential liabilities of the confidential client were identified and comments were prepared for the administrative record.

- *Allied-Signal Goldcamp Disposal Area, Ironton, Ohio: NPL Superfund Site.* Mr. Hail served as ESA's Principal-in-Charge during preparation of Work Plans, pre-design, Remedial Design, and construction phases. Provided technical guidance and assisted with site ground-water investigations, and preparation of the Ground-Water Data Report. He was responsible for internal QA/QC and quality of technical work product.

- *Lower Area One Operable Unit Expedited Response Action, Silver Bow Creek/Butte Area CERCLA Site, Montana.* Mr. Hail provided review and oversight of ground-water modelling, participated in negotiations support, and evaluation of ground-water interaction with the adjacent Montana Pole Plant NPL site. He was responsible for review and construction oversight of dewatering plans for Remedial Design/Remedial Action. He performed a critical review of the RI for the Milltown dam NPL Site in Montana and provided alternative interpretations of ground-water elements of remedial design at the Lower Are One Operable Unit. He provided the client with an informal assessment of the impacts the Montana Pole Plant NPL site would have on the adjacent Lower Area One during remedial action with respect to PCP contamination.

- *Old Works/East Anaconda Development Area Operable Unit, Anaconda Smelter CERCLA Site, Montana.* Mr. Hail provided QA/QC review of Feasibility Studies.

- *Mt. Taylor Uranium Mill Project, New Mexico.* Mr. Hail developed a ground-water discharge plan for disposal of uranium mill tailings including monitoring systems. He provided input to design of uranium mill tailings disposal systems, testified under oath at public hearings, and provided negotiations support with NRC.

- *Rocky Mountain Arsenal Superfund Site, Colorado.* Mr. Hail was principal investigator of ground-water contamination at the north boundary of the arsenal resulting from manufacture of chemical warfare agents, pesticides, herbicides and fungicides. Work included development of a data base for 1,000 monitoring wells defining contaminant plumes, performing and interpreting multiple well pumping tests and development of a ground-water model to support design of a hydraulic barrier/extraction/treatment/ recharge system. This work was performed for the Corps of Engineers, Omaha.

- *Other Mine Sites.* Other mine sites Mr. Hail has worked on include: the Blackbird Mine, ID; DeLamar Mine, ID; Cotter Uranium Mill Tailings Ponds, CO; Section 36 Coal Mine, WY; Skookum Coal Mine, WA; Leviathon Mine, CA; and inspection of 28 Coal Waste Facilities in WV.

Publications

Hail, W.R., Marjerison. J.A., Stephenson, S., and Yadon, D.M. 1995. Remediation of the Warm Springs Pond Complex, Montana. Society of Mining Engineers Annual Meeting.

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Hail, W.R., et al, 1963. Northeastern Counties Ground-Water Investigation. California Department of Water Resources Bulletin, No. 98.

EDMUND J. SCHNEIDER, P.G.
Associate Hydrologist/Engineering Geologist

Academic Credentials
M.S., Geology, Colorado State University, 1975
B.S., Wildlife Biology, Colorado State University, 1968

Professional Licenses
Professional Geologist, Wyoming
OSHA Health/Safety Training for Hazardous Waste Operations
40-hr and 8-hr Supervisory Certification

Key Qualifications

Mr. Schneider is a registered professional geologist with over 20 years of varied experience in hydrogeology, engineering geology and environmental geology. His responsibilities have included project management and technical investigations in soil, geologic and environmental hazard assessments, ground-water quality assessment, data management/data validation, remedial investigations and design, and remedial action construction oversight. Mr. Schneider's hydrogeology and ground water experience ranges from non-intrusive investigations of regional and site-specific hydrogeology and ground-water flow conditions to intrusive field studies for characterization of hydrostratigraphy, ground-water flow paths and aquifer hydraulic properties for a variety of water supply, construction dewatering, environmental impact and hazardous waste site assessments, and remediation projects. His environmental geology project experience includes document reviews, aerial photograph interpretation, site reconnaissance, field mapping, intrusive soil and ground-water investigations, data management/data validation, and geologic hazards assessment. His recent relevant Superfund experience includes engineering evaluation/cost analysis, feasibility studies (alternatives analysis), remedial design and construction oversight/quality control. Mr. Schneider is also experienced in preparation of permit applications, expert testimony at permit hearings, negotiation with regulatory agencies on a variety of environmental investigation/remediation projects, and preparation and implementation of site-specific health and safety plans in accordance with OSHA 29 CFR 1910.120.

Relevant Related Experience

- *Warm Springs Ponds Inactive Area Operable Unit Remedial Action Construction, Montana.* In addition to his technical responsibilities at this site, Mr. Schneider served as Project Manager for construction oversight services for all phases of construction activities, including technical support, field inspections, materials testing and construction quality control. Assistance was also provided for monthly progress reports, agency site inspections, surveying subcontract services, field design modifications, and post-construction activities, including environmental monitoring and operations/ maintenance plans, construction completion report/as-built drawings, and pre-final and final construction inspections. Mr. Schneider directed a field staff of 2 to 4 inspectors, an office staff of 4 engineers, and several subcontractors to accomplish the various oversight tasks.

- *Warm Springs Ponds Operable Unit Soil and Ground Water Remediation, Butte/Silver Bow Creek NPL Site, Montana.* Served as environmental soils investigation leader and hydrogeologist for this operable unit. Mr. Schneider was responsible for development of an ore tailings and associated soils removal protocol on behalf of the client, in lieu of definitive EPA or State of Montana action level criteria for soil remediation. Development of the removal protocol involved extensive field exploration, soil analysis for heavy metals of concern, and statistical quantification of analytical data by material type and by depth within the affected soil profile. The protocol was approved by the EPA and applied effectively during the removal of approximately 430,000 cubic yards of tailings and associated soil materials from a three-mile reach of stream channel to protect the fishery in the Clark Fork River downstream of the site. In addition, Mr. Schneider was responsible for the assessment of ground-water quality and aquifer hydraulic properties required for the analysis and design of ground-water control systems, including ground-water interception and treatment for heavy metals.

- *Rico Site Environmental Assessment Support-Document Review.* Mr. Schneider served as Project Manager in the review of ARCO Rico Site archived files/documents and various other related sources of information. Discharge data and historic water quality data was compiled as a summary of the site background and an annotated bibliography of over 200 database records was created to assist ARCO in the Rico Site Environmental Assessment.

- *Great Falls Refinery Site Assessment, Montana.* Mr. Schneider supported operations in the development/implementation of a successful surface and ground water drainage control program and site reclamation for decommissioned metals refinery facility to alleviate potential off-site releases of heavy metals to the Missouri River. Conducted scoping study to identify extent of impacts to site soils and surface water quality associated with prior metals refining operations and solid waste management. He was responsible for development/management of the soil and surface/water quality studies, data reduction and analysis, and report preparation. Follow-up work included site inspection and recommendations for construction of stable reclaimed fill slopes and lined drainage ditches.

- *Summitville Superfund Site Assessment, Colorado.* Reviewed technical documents from extensive administrative record and conducted site reconnaissance at NPL site subject to severe acid mine drainage conditions for confidential client. The study focused on a qualitative assessment to compare/contrast historic mining/milling operations with recent open pit gold mine/cyanide heap leach operations as major sources of hazardous substances and acid mine drainage in anticipation of potential litigation.

- *Diesel Fuel Spill, Nevada Moly Mine Site, Nevada.* Conducted site investigations to determine extent of infiltration of a diesel fuel spill from storage tank. Investigation included review of operational circumstances associated with the spill, quantity spilled and field excavations to examine depth of infiltration into the ground. A quantitative analysis, based on API guidelines, was performed to confirm that residual fuel in the ground did not pose a potential threat to ground-water quality.

- *Other Site Assessment Experience.* In addition to the previous described experience, Mr. Schneider has participated other assessment projects as follows: Project Manager/Hydrogeologist, historical mining-related sources heavy metals in the ground and shallow ground water, Butte, Montana; Technical Specialist, Twin Buttes Mine/Mill ground-water quality assessment, Arizona; Project Manager/Hydrogeologist, Butte West Camp underground mine flooding assessment and control alternatives analysis, Montana; Solid Waste Specialist, PCB transformer assessment for potential historic mine/mill site acquisitions, Colorado; assessed potential impacts to ground water and provided expert testimony for approved Underground Injection Control permit application for of sewage treatment plant effluent as an acceptable alternative to a point discharge to the prestine Snake River, Wyoming.

Publications

Nuckolls, H.M., Yadon, D.M., and Schneider, E.J., 1991, Remediation of Mining Wastes, Silver Bow Creek/Butte Area Superfund Site, Montana: presentation to the Irish Association for Economic Geology Course on Environmental Aspects of Exploration and Extraction.

DOUGLAS M. YADON, P.E.
Associate Civil/Geotechnical Engineer

Academic Credentials
M.S., Civil (Geotechnical) Engineering, Stanford University, 1976
B.S., Geology and General Engineering, Oregon State University, 1974

Professional Licenses
Professional Civil Engineer: Colorado, Montana, Wyoming, Utah, California, Ohio;
Geologist/Engineering Geologist: Oregon, Idaho
OSHA Health/Safety Training for Hazardous Waste Operations - 24-hr Certification

Key Qualifications

Mr. Yadon is a registered professional engineer and certified engineering geologist with more than 21 years experience in the fields of Civil, Environmental and Geotechnical Engineering, and Environmental Geology. He has applied his academic training and professional experience to civil/environmental projects involving: surface and ground-water development and remediation; petroleum refineries, pipelines and related facilities; metals mining, processing and refining facilities; fossil fuel, geothermal and nuclear power plants; hazardous and non-hazardous waste sites; and military facilities. Mr. Yadon's practice ranges from site assessments and investigations, to detailed analyses and designs of earth structures and remediation measures, through preparation of plans and specifications and construction/remedial action oversight, and includes short and long-term monitoring and data collection programs.

In addition to his technical capabilities, Mr. Yadon has developed a familiarity with various aspects of environmental and related regulations including CERCLA/SARA, NEPA/CEQA and RCRA. His experience in this regard includes directing and/or assisting the development of work plans, quality assurance project plans (QAPP), field sampling plans (FSP), laboratory testing plans (LTP), site-specific safety and health plans (SHP), and related documents. Mr. Yadon has broad experience interacting and/or negotiating with regulatory/oversight agencies, including EPA, U.S. Forest Service, Ohio EPA, Montana Department of Health and Environmental Sciences, CalTrans and various California Counties including Kern, Santa Barbara and Ventura (with regard to oil load/off-load and pipeline facilities), various State Engineers offices, U.S. NRC and others.

Relevant Related Experience

- ***Rio Tinto Mine Site Assessment, Nevada.*** Mr. Yadon served as project manager and one of two lead investigators for a confidential, non-intrusive environmental site assessment in support of the client's legal staff for this abandoned mine site in Northern Nevada. The assessment included: review of historic data and reports, and topographic maps and aerial photographs relevant to the site; site reconnaissance; and meetings. A memorandum was prepared presenting remedial design concepts addressing the issues raised by the Nevada Department of Environmental Protection, including preliminary cost estimates. Also, a critical review was performed of a conceptual remedial design prepared for previous owners of the site.

- ***Warm Springs Ponds Active and Inactive Operable Units, Butte/Silver Bow Creek CERCLA Site, Montana.*** Mr. Yadon served as Project Manager/Lead Designer on major multi-discipline remedial design/remedial action at the world's largest Superfund site. This project included design-level field investigation, laboratory testing and design of raising/ strengthening several miles of earth embankments to withstand the site Maximum Credible Earthquake (MCE) and one-half the Probable Maximum Flood. The site MCE was developed from evaluation of pertinent available geologic and seismologic data for the region. As part of the field investigations, several hundred test pits and borings were completed, and over a hundred piezometers were installed at the site. As responsible engineer, Mr. Yadon directed final design and preparation of plans and specifications for more than 36 million dollars of remedial construction to date on the Warm Springs project. In addition to the RD/RA work, the early stages of this project involved substantial site assessment and feasibility study elements.

- ***Allied-Signal Goldcamp Disposal Area Operable Unit, Ironton Coke CERCLA Site, Ohio.*** As ESA's overall project manager, Mr. Yadon directed all geotechnical exploration, testing and remedial design elements of remediation of an uncontrolled waste pit at the Ironton coke/tar plant. The primary contaminants at the site include various organic compounds in volatile and DNAPL/LNAPL forms. Remediation elements include groundwater extraction and treatment, a soil-bentonite barrier wall and a RCRA-compliant composite earth/synthetic liner with gas venting capability.

- ***Lower Area One Expedited Response Action, Silver Bow Creek/Butte Area CERCLA Site, Montana.*** Mr. Yadon served as ESA's internal Quality Assurance/ Quality Control Officer during design phases of the project. He reviewed technical approaches and methodologies, Work Plans and Design Reports (including Technical Specifications and Drawings) in terms of completeness, applicability and conformance to ARARs, Performance Standards and other pertinent criteria and standards.

- ***Old Works/East Anaconda Development Area Operable Unit, Anaconda Smelter CERCLA Site, Montana.*** Mr. Yadon provided design review of selected elements of the work, and on-site construction oversight/ consultation during the remedial action phase of this project.

- ***Rocky Mountain Arsenal, Colorado (for corps of Engineers, pre-CERCLA).*** Mr. Yadon served as ESA's Project Manager for the Liquid Waste Disposal Facility - Basin F. He planned and implemented site investigation, including soils sampling and testing to characterize on-site borrow materials.

- ***Tosco Refineries RCRA Compliance Project.*** Mr. Yadon directly participated in four RCRA compliance projects for existing petroleum refineries at sites in California (2), Oklahoma and Arkansas. The projects included detailed review of available site geologic, hydrogeologic and contaminant information; site reconnaissance; site characterization, including hazardous and non-hazardous waste management facilities; and development of RCRA-compliant ground-water monitoring plans.

- ***Various Crude Oil Pipeline EIS/EIR Projects.*** As geology/geotechnical discipline leader, Mr. Yadon has participated in several major PEA, EA and/or EIS/EIR efforts for proposed crude oil pipelines and associated off-loading and other appurtenant facilities. These projects include: Celeron/All-American Pipeline, California to Texas; Getty-Gaviota Consolidated Coastal Facility, California; Angeles Pipeline, California; Pacific Pipeline System, California; and Cave Creek Sour Gas Gathering System, Wyoming.

- ***Gary Energy Refinery Conversion Project, Colorado.*** The Gary Energy refinery was to be converted from conventional oil refining to refining of jet fuel from oil shale. As a key member of the project team, Mr. Yadon participated in a detailed environmental assessment of this site located on the banks of the Colorado River. The assessment included thorough review of plant waste stream flow records as part of modeling ground-water flows and potential impacts to the alluvial aquifer and the river.

- ***Mt. Konocti Class II-1 Geothermal Waste Disposal Site Project, California.*** As project engineer/geologist, Mr. Yadon performed a review of available geologic, hydrogeologic and topographic/geomorphic data, and a field exploration and laboratory testing program as part of a detailed assessment of a proposed site in Lake County, California. for disposal of geothermal drilling wastes.

- ***Leviathan Mine AMD Control/Design Review, California.*** Mr. Yadon participated in critical review of an AMD control design prepared by others for this inactive mine in Northern California. In addition to evaluation of engineering design concepts and details, he prepared an independent estimate of the construction cost of the proposed control measures.

- ***Master Environmental Assessment (MEA), Geysers-Calistoga Known Geothermal Resource Area, California.*** As a lead investigator, Mr. Yadon was heavily involved in all aspects of this environmental assessment project for the California Energy Commission. The project included acquisition and compilation of a vast amount of existing information on geologic, geomorphic, surface and ground-water aspects of the natural environment. Given the available data and proposed geothermal drilling and power production actions, a detailed assessment of potential environmental impacts was made, and appropriate mitigation measures developed for unavoidable adverse impacts.

Publications

Jewell, Alan C., P.E., Yadon, Douglas M., P.E., Pierce, Steven J. and Patrick L. Redmond. 1994. Geotextile reinforcement of wet-closure dikes over very soft tailings, in: Geosynthetics Case Studies Book for North America; North American Geosynthetic Society and Canadian Geosynthetic Society Subcommittee on Geosynthetics.

Hail, W.R., Marjerison. J.A., Stephenson, S., and Yadon, D.M. 1995. Remediation of the Warm Springs Ponds Complex, Montana. Society of Mining Engineers Annual Meeting.

Pierce, S.J, Yadon, D.M., Miller, D.J. and Jewell, A.C. 1994. Geotechnical aspects of dam safety improvements for water treatment detention ponds - Warm Springs Ponds Operable Unit, Montana, USA, in: Tailings and Mine Waste '94, Proceedings of the First International Conference on Tailings and Mine Waste '94, Fort Collins, Colorado, USA, 19-21 January 1994.

Nuckolls, H.M., Yadon, D.M., and Schneider, E.J. 1991. Remediation of Mining Wastes, Silver Bow Creek/Butte Area Superfund Site, Montana: presentation to the Irish Association for Economic Geology Course on Environmental Aspects of Exploration and Extraction.

Yadon, D.M., Kuiken, J.G., and Miller, S. 1989. The breaching of Green Lakes No. 2, in: Colorado Water Engineering and Management Conference, Colorado State University, February 27-28.

Yadon, D.M. 1986. Investigation of the Kennedy Gulch fault at Reynolds Park: in Contributions to Colorado Seismicity and Tectonics - A 1986 Update; Colorado Geological Survey Special Publication 28, Denver, Colorado.

Yadon, D.M. 1979. On academic training for engineering geologists: thoughts of a recent graduate: Geological Society of America, Abstracts with Programs, panel presentation at 1979 Annual Meeting, San Diego, California.

Yadon, D.M., and Wright, R.H. 1979. Evidence for recent faulting in the Pleasanton area, California, in Recent deformation along the Hayward, Calaveras, and other fault zones, eastern San Francisco Bay region, California: Geological Society of America, Field Trip Guidebook, 75th Annual Cordilleran Section Meeting, San Jose, California.

Shelmon, R.J., Yadon, D.M. and Harding, R.C., 1979, Dating late Quaternary slip-surface displacement by soil-stratigraphic techniques: Geological Society of America, Abstracts with Programs, 1979 Annual Meeting, San Diego, California.

Wright, R.H., Harding, R.C. and Yadon, D.M., 1979, The Las Positas fault, Alameda County, California: an example of subsidence and/or tensional tectonics: Geological Society of America, Abstracts with Programs, 75th Annual Cordilleran Section Meeting, San Jose, California.

WILLIAM R. KELLY, P.E.
Supervising Civil/Hyraulic Engineer

Academic Credentials
B.S. Civil Engineering, Colorado State University, 1970;
Health/Safety Training for Hazardous Waste Operations, OSHA 29 CFR 1910.120, 1990

Professional Licenses
Professional Engineer, Colorado, Wyoming and Montana

Key Qualifications

Mr. Kelly is a registered professional engineer with 23 years varied experience as an engineering consultant in the areas of environmental and civil engineering. His responsibilities have included project management, technical evaluation, design, inspection, and construction contract administration. He has extensive experience in dealing with the EPA and State Regulatory Agencies. Relevant technical experience has included field reconnaissance of existing facilities and conditions, water quality assessment, data management, and evaluation, planning, design, construction and operation of pollution control facilities and remediation projects.

Relevant Related Experience

- *Warm Springs Ponds Operable Units, Silver Bow Creek CERCLA site, Montana.* Supervising Engineer for Hydraulics, Hydrology and Treatment Remedial Design. Served as resident engineer on major emergency response removal action. Evaluated historic removal performance of existing Ponds treatment system and predicted potential to achieve new performance standards after modifications. Designed new lime treatment facilities to enable pH control of Ponds system for flows ranging from 20 cfs to 3,000 cfs. Performed hydraulic modeling of Silver Bow Creek 70,000 cfs, 0.5 PMF, design storm for bypass around ponds and designed hydraulic facilities to protect system. Developed approach to maintaining compliance with water quality standards during flooding of tailings and implementation of new pond wet-closure facilities. Designed treatability study, computerized environmental data collection and monitoring system, sedimentation control facilities, new groundwater interception and pumping facilities, flow measurement facilities, and hydraulic structures. Prepared Operations and Maintenance manual for facilities. Participated extensively with Client, EPA and State agencies in developing project criteria and obtaining approvals.

- *Rhone-Poulenc Basic Chemicals, Silver Bow Facility, Butte, Montana.* Served as project manager and engineer to evaluate existing lime feed facilities and pH control of air scrubber water discharge/plant water recirculation. Evaluated suitability of existing lime slaker, identified deficiencies in prior operations and functional limitations in achieving satisfactory pH control of various process sources. New system with proper controls was designed to fit into existing limited space while maintaining critical 24-hour/7 day per week operation.

- *Aero Space Facilities Environmental Audit, Denver, Colorado.* Conducted Site inventory and assessment of environmental risks for industrial pretreatment facilities. Evaluated process and performance of existing facilities and proposed modifications. Identified and documented potential spills and associated risks of facilities and various chemicals utilized throughout the site. Principal components removed at the site were volatile organics and heavy metals.

- *Rocky Mountain Arsenal Basin F Investigations, Denver, Colorado.* Project Engineer for study of chemical solidification as an alternative for decontamination of Basin F. Included process selection, preliminary design, equipment selection, and preparation of estimates for capital and operation and maintenance costs. A separate project involved preparation of specifications for pilot scale test burn incineration of Basin F contents.

- *Summitville Superfund Site Assessment, Colorado.* Reviewed selected technical documents and conducted site reconnaissance at NPL site subject to severe acid mine drainage conditions for confidential client. Prepared conceptual design and feasibility cost estimate for alternative remediation approach.

- *Manufacturing Site, Georgia.* Prepared construction drawings for tank farm and chemical handling facilities to remove phenol and formaldehyde from exhaust system. The project included a two stage packed tower using sodium hydroxide and sodium bisulfite recirculation systems. Also prepared construction drawings for formaldehyde chemical feed system supply to padders used in manufacture of transmission belts.

- *Industrial Wastewater Pretreatment Facility for proposed sheepskin tannery, Montecello, Utah.* Completed alternative investigations and preliminary design for Chrome Tan Facility processing 8000 skins per day. The project included process calculations for pretreatment facilities, evaluation of impact on municipal facilities, preliminary design layout, equipment selection and cost estimating.

- *Water and Wastewater Treatment Facility Design Experience.* Has been instrumental in the planning, design and operation of over thirty treatment facilities. Experience has involved site evaluation for process suitability, including, as appropriate, site acquisition, flow monitoring including sampling and measurement, data review, historic loading and performance evaluation, design capacity identification, treatment process evaluation and selection, equipment evaluation, selection and layout, hydraulics calculations, site development including utilities, drainage, and access considerations. Facilities designed have included biological treatment, physical/chemical treatment, and alternative treatment technologies such as land application, infiltration/percolation systems, and groundwater recharge. Clients have included various municipalities, private industry and the federal government (i.e., DOE at Idaho Falls, and Rocky Flats, and the Air Force at Colorado Springs).

Cedar Creek Associates

STEPHEN G. LONG

EXPERIENCE ABSTRACT

Employed for 17 years in the environmental field, 15 as a consultant with multi-disciplinary responsibilities including service as corporate officer, project manager/strategist, revegetation specialist, soil scientist, revegetation field supervisor/coordinator, wetlands specialist and vegetation/wildlife field technician. Project management responsibilities have included client/agency liaison, project risk analysis, technical editing, personnel management, cost control, and quality assurance evaluation. Experience also includes mine inspection and personnel management.

Career accomplishments include authorship of, or technical contribution to:

65 Revegetation Plans • 27 EIS/EA documents • 23 Bond/Construction Cost Estimates • 5 Revegetation Test Plot Programs • 12 Mine Permit Reviews/Revisions • 44 Wetland Projects • 21 Vegetation Surveys • 13 Soil Surveys • 12 Wildlife Surveys • 19 Property Transfer Evaluations • Permit Strategy Development for Numerous Projects • 2 Revegetation Manuals and 8 Technical Papers • Expert Witness Testimony and Lectures

Types of projects have included:

Hard Rock Mines • Wetland Disturbances • Municipal Developments • Pipelines • Water Projects • Coal Mines • Corridor Analyses • Gas and Synfuels Developments • Abandoned Mines • Power Plants • Gravel and Borrow Pit Permits • Real Estate Projects and Other Private Land Holdings • Golf Courses

Involved in over 135 projects including work in:

Northern Great Plains • Rocky Mountains • Desert Southwest • Pacific Northwest • Intermountain Region • Appalachia • California • Alaska

EDUCATION AND CERTIFICATIONS

B. S., Wildlife Biology, Colorado State University - 1972
M. S., Regional Resource Planning/Soil Science-Reclamation, Colorado State University - 1977
Associate Wildlife Biologist - The Wildlife Society
Certified Soil Erosion and Sediment Control Specialist - ARCPACS
40-Hr. OSHA Certification (OSHA Reg 29 CFR 1910.120)
Desert Tortoise Survey and Examination Techniques
Black-footed Ferret Survey Techniques- U. S. Fish and Wildlife Service

EMPLOYMENT HISTORY

Cedar Creek Associates, Inc. - 1982 to Present
Environmental Research & Technology, Inc. - 1977 to 1982 (Presently ENSR)
Ohio Department of Natural Resources, Division of Reclamation - 1972 to 1974

REPRESENTATIVE CLIENTS

Anaconda Copper Co. (NV) • Atlantic Richfield Co. (CO) • AT&T (NV) •Chevron Shale Oil Co. (CO) • City of Bellevue (OH) • City of Boulder (CO) • City of Fort Collins (CO) • Coaleum Corp. (W.V) • Consolidation Coal Co. (ND) • Coteau Properties Co. (ND) • Diamond Shamrock Corp. (AK) • Eureka Energy Co. (UT) • Exxon Minerals Co. (NM) • Falkirk Mining Co. (ND) • Freeport Gold Co. (NV) • Getty Mining Co. (CO) • Goldenbell Mining Corp. (CA) • Gulf States Energy Corp. (KY) • Hewlett-Packard Co.(CO)• Houston International Minerals Corp. (NV) • J & P Corp. (WY) • Montco (MT) • Northwest Pipeline Corp. (CO) • Northern Tier Pipeline Co. (MN, MT, ND, WA) • Peabody Coal Co. (MT) • Platte River Power Authority (CO) • Retech (CO) • Rocky Mountain Energy Co. (WY) • Simons, Li & Associates, Inc. (CO, UT, WA, Africa) • Sunedco (UT) • Texas Energy Services, Inc. (WY) • Town of Breckenridge (CO) • U. S. M. X. (NV) • U. S. Congress (Western U. S.) • U. S. Fish and Wildlife Service (Western U. S.) • U. S. Forest Service (ID, MT, NV) • Utah Division of Oil, Gas and Mining (UT)

EXPERIENCE SPECIFICS

Mr. Long's education and years of environmental and regulatory compliance experience have facilitated the development of specialized multi-disciplinary skills for use on mining, wetland disturbance, urban and water development, power plant construction, and corridor assessment/restoration projects. His areas of expertise include permitting and project management, revegetation planning, wetland delineation and mitigation, soil science, and wildlife habitat restoration, among others.

PERMITTING AND PROJECT MANAGEMENT. Mr. Long has successfully managed, coordinated, and overseen development of technical documents for projects varying widely in size, scope, and objectives. Responsibilities have included project/permit strategy development, technical editing, cost analysis, personnel scheduling, and quality control. He frequently serves in a liaison capacity between clients and regulatory agencies. In addition, Mr. Long has successfully reviewed, edited, and revised sections of existing deficient permit applications and achieved subsequent regulatory approval. In a related capacity, Mr. Long completed 19 on-site property and permit evaluations for private companies seeking to expand their holdings. He also has contributed to 27 NEPA documents for various permit documents. Examples of permitting projects in which he has participated or managed, include various state and federal coal mine and hard rock permit applications, CMLRD gravel mine applications, and Corps of Engineers Nationwide 26, PDN-26, and "Individual" permit applications.

REVEGETATION. Mr. Long has completed revegetation and restoration plans for 65 disturbances including those associated with surface and underground coal mines, hard rock mines, wetlands, municipalities, water developments, abandoned mines, pipeline and power plant construction sites, and synfuels exploration disturbances. These plans addressed a wide range of general objectives including site stabilization, erosion control, reestablishment of livestock grazing capacity, critical big game winter range, and aesthetics as well as specific objectives such as wetland and riparian system restoration, woody draw reconstruction, and moose and pronghorn antelope habitat enhancement. Typical plans include a soil handling program with soil mass balancing, site preparation details, fertilizer application recommendations, planting procedures, site-specific planting mixtures, soil stabilization specifications, and maintenance recommendations as well as bond/construction cost estimates. In addition, Mr. Long has been involved in the design and implementation of five revegetation test plot projects completed to determine the effects of slope, aspect, seeding and planting methods, species selection, seedbed material type, and time of seeding on revegetation success potential. He has coordinated and personally implemented revegetation and erosion control programs in the field and served as a revegetation inspector in Ohio with responsibility over 61 active mine operations. Mr. Long has served as an expert witness on the subject of revegetation for two hearings. He has authored two revegetation manuals, <u>Characteristics of Plants Used in Western Reclamation</u> and <u>Handbook of Revegetation Techniques</u>, which have received wide academic, regulatory, and industry distribution throughout North America.

SOIL SCIENCE. Mr. Long has participated on 13 Order 2 and Order 3 soil survey projects designed to characterize soil properties and develop soil handling plans. He has completed numerous field sampling projects designed to assess seedbed material growth potential capabilities, soil microbial populations, soil fertility conditions, and toxic constituent levels. In addition, Mr. Long has evaluated a wide range of soil mapping and laboratory data culminating in his authorship of several soil technical reports for EIS, EA, pipeline corridor, and mine permit documents.

WETLAND BIOLOGY, RANGE SCIENCE, and WILDLIFE. Mr. Long has completed 44 wetland mapping, permitting, and/or restoration projects in the west, responsive to COE, state and local regulations. He has been involved in 21 vegetation surveys responsive to various permitting requirements. Vegetation experience includes measurement of plant density, canopy cover, diversity, and current annual production as well as specific surveys for T&E species. Wildlife experience includes participation in aerial or terrestrial surveys for mule deer, antelope, mountain goats, black-footed ferrets, goshawks, determination of big game distributions, and preparation of wildlife report sections. He also has experience in desert tortoise monitoring (450 field hours) for construction projects.

PUBLICATIONS

Fullerton, W.T. and S.G. Long. 1989. Wetland creation in a river valley disturbed by dredge boat mining. pp. 297-306. In: Fisk, D.W. (Ed.). Wetlands: Concerns and Successes (Symposium Proceedings). Tampa, Florida. American Water Resources Association. Bethesda, Maryland.

Long, S. G. 1978 (first edition). 1980 (second edition). Characteristics of plants used in western reclamation. Environmental Research & Technology, Inc., Fort Collins, Colorado. 138 pp.

Long, S. G. 1982. Analysis of geotextiles and their potential use in cut-and-fill revegetation. U. S. Forest Service, Missoula, Montana.

Long, S. G. 1985. A seeding technique to enhance species diversity. pp. 279-282. In: Williams, D. and S. E. Fisher, Jr. (Co-chairmen). Second Annual Meeting: American Society for Surface Mining and Reclamation. Denver, Colorado.

Long, S. G. and S. L. Ellis. 1984. Revegetation guideline development for pipeline rights-of-way. pp. 233-244. In: Crabtree, A. F. (Ed.). Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management, San Diego, California. Mississippi State University, Mississippi.

Long, S. G. and S. L. Ellis. 1987. Results of woody species test plots established on a mine exploration site in Alaska. pp. 245-258. In: Schuster, M. A. and R. A. Zuck (Eds.). Proceedings: High Altitude Revegetation Workshop No. 7. Colorado State University, Fort Collins, Colorado.

Long, S. G., J. K. Burrell, N. Laurenson, and J. H. Nyenhuis. 1984. Handbook of revegetation techniques (cut-and-fill slopes, mined lands, watershed projects, range improvements). U. S. Forest Service. Missoula, Montana. 145 pp.

Lynch, D. L. and S. G. Long. 1977. A management plan for the McGregor Ranch (Estes Park, Colorado). Colorado State University, Fort Collins, Colorado. 46 pp.

Phelan, T. M., S. R. Viert, and S. G. Long. 1986. Wildlife technologies for western surface coal mining. pp. Office of Technology Assessment, U. S. Congress, Washington, D. C. 183 pp.+ appendices.

<u>Contributing Author to</u>:

Moore, R., and T. Mills. 1977. An environmental guide to western surface mining, part two: impacts, mitigation, and monitoring. Western Energy and Land Use Team, U. S. Fish and Wildlife Service Publication FWS/OBS - 78/04. Misc. pagings.

Numerous technical discipline reports concerning revegetation, wetlands, soil science, vegetation, and other environmental topics

CEDAR CREEK ASSOCIATES, INC.

STEVEN R. VIERT

EXPERIENCE ABSTRACT

Employed as an environmental consultant since 1977. Responsibilities include service as corporate officer, project manager, permitting specialist, range ecologist, and wildlife biologist. Project management activities include interdisciplinary coordination, subcontractor supervision, client/agency liaison, cost control, critical path scheduling, overall planning, and quality assurance.

Career accomplishments include authorship of, or technical contribution to:

43 NEPA Documents • 21 Permit Evaluation/Audits/Revisions • Strategy Development, Agency Liaison, Permit Preparation for Numerous Projects • 71 Vegetation Baseline/Community Mapping Studies • 66 Vegetation Impact Assessments • 37 Wetland Evaluations • 32 Revegetation Success/Bond Release Determinations • 51 Wildlife Baseline/Habitat Studies • 46 Wildlife Impact Assessments/Mitigation Plans • Threatened and Endangered Species Evaluations (37 flora, 35 fauna) • 15 Land Use Evaluations/Reviews • 4 Alluvial Valley Floor Assessments • State-of-the-Art Riparian Investigations & Expert Witness Testimony • Management of 2 Complete Coal Mine Permit Applications

Types of projects have included:

Hard Rock Mines • Coal Mines • Litigation Support • Wetland Evaluations/Enhancement • Riparian Assessments • Corridor Analyses • Water Developments • Synfuels Projects • Abandoned Mines • Power and Other Industrial Plants • Superfund Remedial Investigations

Involved with 170 projects including work in:

Desert Southwest • Northern and Central Great Plains • Rocky Mountains • Pacific Northwest • Intermountain Region • West Coast • Midwest • Alaska

EDUCATION AND CERTIFICATIONS

B. S., Wildlife Management, University of Michigan, 1974
M. S., Range Ecology, Colorado State University, 1975
M. B. A., Finance/Land Use Management, Colorado State University, 1982
Certified Wildlife Biologist - The Wildlife Society
Certified in Habitat Evaluation Procedures (HEP) - U. S. Fish and Wildlife Service
Black-footed Ferret Survey Techniques - U. S. Fish and Wildlife Service
Desert Tortoise Survey and Examination Techniques

EMPLOYMENT HISTORY

Cedar Creek Associates, Inc. - 1982 to Present
Environmental Research & Technology, Inc. - 1977 to 1982 (presently ENSR Corporation)
Colorado Division of Wildlife - 1974 to 1975

REPRESENTATIVE CLIENTS

AT&T (CA,.NV) • BHP-Utah International Inc. (UT) • Chevron Shale Oil Co. (CO) • Cities of Boulder, Breckenridge, Fort Collins, Loveland, and Pueblo (CO) • Colorado Attorney General • Diamond Shamrock Corp. (AK) • El Paso Natural Gas Co. (NM) • Energy Fuels Co. (CO) • Exxon Minerals Co. (NM) • Falkirk Mining Co. (ND) • FMC Gold Corp. (ID, MT, NV, WY) • Freeport Gold Co. (NV) • Getty Mining Co. (CO) • Homestake Mining Co. (NV) • Inspiration Mining Co. (NV) • Kern River Gas Trans. Co (WY) • Meridian Land & Minerals Co. (MT, CO, NV, SD) • North American Coal Co. (ND) • Office of Technology Assessment, U.S. Congress (Western U.S.) • Pacific Gas and Electric Co. (UT) • Peabody Coal Co. (AZ, CO, WY) • Platte River Power Authority (CO) • Rocky Mountain Energy Co. (WY) • Simons, Li & Associates, Inc. (CO, UT, WA, Africa) • Sunedco Coal Co. (UT) • BLM (AZ, UT, NV) • USFS (ID, MT, NV) • U.S. Sprint (CA,ND) • Utah DOGM (UT) • Western Energy Co. (MT) • W.R. Grace Co. (UT) • WIDCO (WA)

EXPERIENCE SPECIFICS

Mr. Viert's education and several years of environmental and regulatory compliance experience have facilitated development of specialized multi-disciplinary skills for projects in mining, industrial and urban land development or rehabilitation, corridor assessment, wetland evaluation/restoration, and water development. Areas of expertise include permitting and project management, vegetation and range ecology, wildlife / habitat ecology, bond release evaluations, and land use classification/evaluation.

PERMITTING AND PROJECT MANAGEMENT. Mr. Viert has been actively involved in all phases of permit application development from feasibility analyses to the assessment of reclamation success for the release of bonds. Permitting and management responsibilities have included overall permit preparation, strategy formulation, client/agency liaison, regulatory compliance evaluation, subcontractor supervision, critical path scheduling, cost control, quality assurance, and technical document editing for a variety of projects. Permitting projects have ranged from small 404 applications to large NEPA compliance efforts. Of particular note are two large management efforts leading to the successful acquisition of SMCRA permits for a 12.5 million TPY coal mine in the Powder River Basin of Wyoming and a 5 million TPY underground coal mine in the Book Cliffs of Utah. Mr. Viert's permitting experience and related interactions with regulatory agencies for development projects and associated permit application submittals have provided him with a working knowledge of the policies and regulations of several state and federal agencies such as OSMRE, COE, NRC, FERC, BLM, USFS, USFWS, CMLRD, WDEQ, UDOGM, NDPSC, NM-MMD, NDEP., among others. Mr. Viert's project management experience has been gained on projects ranging from single discipline evaluations (e.g., wetlands) to large multi-disciplinary efforts (including engineering, legal, environmental, and reclamation) for mining and other development projects.

VEGETATION/RANGE ECOLOGY. Mr. Viert has completed over 90 vegetation studies and assessments for a wide range of projects including litigation (riparian issues between the state of Colorado and the USFS), surface and underground coal mines, hard rock mines, synfuel developments, corridor assessments for power and communication lines, pipelines and transportation arterials, water developments, abandoned mines, and municipal developments. Study components of these projects have included: floral measurements (cover, density, production, etc.), statistical design and analyses, community mapping, impact assessment and mitigation planning, determination of general range condition and community dynamics, evaluation of livestock carrying capacity and management, forest measurement, and development of revegetation success standards and bond release criteria. In addition, he has evaluated sensitive issues such as wetlands and threatened and endangered species. He also has assisted in the development of several revegetation planning efforts and, as discussed below, designed and implemented a number studies for post-revegetation monitoring to determine revegetation success for bond release. In 1977, Mr. Viert pioneered the development and use of the Optical Point Bar, a new instrument for economically and precisely measuring ground cover which is used in most analyses of vegetation.

RECLAMATION SUCCESS AND BOND RELEASE DETERMINATIONS. In this specialized field, Mr. Viert has been very actively involved in state-of-the-art design and implementation of site-specific technical studies for a large number of mining companies, especially coal. These studies are designed to be the most potentially successful, defensible, practical, and economical methods of analyses to facilitate the release of bond monies. Mr. Viert has successfully negotiated with State and Federal Agencies for both the implementation of such designs as well as aided negotiations for the eventual release of bonds.

WILDLIFE BIOLOGY. In this field, Mr. Viert has been actively involved in over 60 wildlife studies and impact assessments for various mines and land developments. Technical capabilities in this field include habitat evaluation and mapping, large mammal population studies, upland game animal surveys, general baseline measurement, sensitive and threatened or endangered species evaluations [especially for black-footed ferret and desert tortoise (over 1600 hours of survey/monitoring)], impact assessment, state-of-the-art mitigation planning, and aquatic sampling.

OTHER technical capabilities include land use assessment and classification, alluvial valley floor evaluation, and farm/ranch economic assessment.

PUBLICATIONS

Viert, S. R. 1989. Design of restoration methods to encourage fauna. In: J. D. Majer, PhD (Ed.). Animals in primary succession - the role of fauna in reclaimed land. Cambridge University Press, London, England.

Viert, S. R. 1985. A new instrument for measuring ground cover based on the point-hit technique - the optical point bar. Proceedings of the 1985 Annual Meeting of the American Society for Surface Mining and Reclamation, Denver, Colorado, October 8-10. 4 pp.

Phelan, T. M. and S. R. Viert. 1986. Prairie dog and black-footed ferret surveys in northeast and east-central Utah. Cedar Creek Associates, Inc. 31 pp. + appendices.

Phelan, T. M. , S. R. Viert, and S. G. Long. 1986. Wildlife technologies for western surface coal mining. Office of Technology Assessment, U. S. Congress, Washington, D. C. 183 pp. + appendices.

Numerous technical discipline reports concerning vegetation, range ecology, wetlands, wildlife, and other environmental topics

Environmental Management Services (EMS)

GAST, THOMAS E.

ENVIRONMENTAL MANAGEMENT SERVICES COMPANY (1981 - Present)

As a principal of the firm, Mr. Gast has responsibility for all phases of multidisciplinary programs as project manager. He has authored or co-authored over 30 NEPA documents for projects located on BLM, Forest Service and Parks Service lands. Mr. Gast has extensive knowledge of and has prepared and defended Federal, State and local permits for mining projects throughout the west. His permitting experience includes surface and underground mines, cyanidation, flotation, and gravity separation mills, precious metals refining processes, and various industrial mineral mines, mills and quarries. Mr. Gast has conducted over 100 due diligence and preacquisition studies.

TRC ENVIRONMENTAL CONSULTANTS, INC. (1979-1981)

As a senior minerals project manager in the Denver, Colorado office, Mr. Gast had responsibility for project design; study execution; permit development and negotiation; agency and client interaction and costs and schedules.

ENVIRONMENTAL RESEARCH AND TECHNOLOGY, INC. (1977 - 1979)

Mr. Gast was operations manager for the Fort Collins Technical Center of ERT and was line manager for 75 professionals of various disciplines located in four regions of the U.S.

AMERSHAM/SEARLE CORPORATION (1970 - 1977)

Mr. Gast was a project manager for this division of the U.K. Atomic Energy Authority.

PROJECT EXPERIENCE —

Project Manager. Technical review of remedial investigations and feasibility studies conducted by EPA's contractor for a Superfund mining site located in Rio Grande County, Colorado. Responsible for review of all aspects of EPA's action, preparation of comment letters, and strategy development for one of the defined Potential Responsible Parties (PRPs). *Summitville Mine Site - for Confidential Client.*

Project Manager. Environmental review; permits preparation and defense in support of this major underground exploration mine located within five miles of Vail, Colorado. Colorado and Eagle County prospecting and mining permits and state air and water quality permits were prepared. This project was the first underground exploration project permitted under the Prospecting Regulations in Colorado and approval required Board review and concurrence. Following exploration, final reclamation and bond release was negotiated. The reclaimed site won the Governor's Award due to innovative slope stabilization techniques. *Gold Fields Mining Corporation - Red Cliff Project.*

Project Manager. Responsible for pre-acquisition due diligence studies of this historically important silver-base metal mine located near Ouray, Colorado. Permits prepared to date include a Construction Dewatering Permit to allow underground access for drainage tunnel repair, an NPDES Permit for 1,500 gpm mine drainage and Reclamation Permit maintenance. *Sunshine Mining and Refining Company - Revenue-Virginius Project.*

Project Manager. Technical review of remedial investigations and feasibility studies conducted by EPA's contractor for a Superfund mining site located in Eagle County, Colorado. Responsible for review of all aspects of EPA's action. *Eagle Mine Site - for Confidential Client.*

Project Manager. Technical review of remedial investigations and feasibility studies conducted by contractors for a mining site subject to Natural Resource Damages located in southwest Colorado. *Idarado Mine Site - for Confidential Client.*

Project Manager. Responsible for pre-acquisition due diligence studies of this gold exploration project located near Ouray, Colorado. Since the gold is found with massive pyrite in the Pony Express beds, the 110 Mining Permit application was prepared in accordance with the recent Colorado Designated Mining Operation (DMO) regulations as administered by Colorado Division of Minerals and Geology and Department of Health. *Sunshine Mining and Refining Company - Ouray Gold Project.*

Project Manager. Environmental reconnaissance studies, permits preparation, compliance, reclamation and bond retrieval for diamond exploration program. Multiple exploration sites were permitted in Colorado, Wyoming and Arkansas. *The Superior Oil Company, Minerals Division - Diamond Exploration Program.*

Project Manager. Responsible for baseline studies and primary author of joint BLM/NDEP mining and reclamation permits and BLM extensive EA for this 12-year, 1,500 tonne per day major expansion of this existing open-pit mine. Because of the project's close proximity to Death Valley National Monument and the historically important Ryolite site, major issues addressed in the EA included ground-water, blasting and the effects on Beatty of phasing out 100 surface miners and replacing them with 100 underground miners. *Lac Minerals, Inc. - Bullfrog North Underground Expansion.*

Project Manager. Responsible for conducting due diligence survey of Canyon Resources mines and advanced stage exploration projects. The work included permit and compliance review, reclamation plan review and environmental cash flow estimation from the time of the study through closure, reclamation and bond release. The properties included the Kendall, 7-Up Pete, and McDonald Meadows in Montana; Beartrack in Idaho; and Briggs in California. *Watts, Griffis and McQuat Limited for confidential client.*

Project Manager. Responsible for joint NDEP/Forest Service Reclamation Plans for these underground and surface mines, and processing facilities. The project included review of all outstanding permits and approved plans dating to 1978, development of a Reclamation Plan consistent with the new regulations and reclamation cost estimating. *Marshall Earth Resources Inc. - Ione and Berlin Projects.*

Project Manager. Responsible for all baseline studies, permit application preparation and co-author of the BLM EA for this 2,000 ton per day open-pit, heap leach gold mine located in central Nevada. *Corona Gold Inc. - Santa Fe Mine.*

Project Manager. Environmental reconnaissance; baseline studies; permits preparation and testimony for an open-pit gold mine, 3,000 tons per day autoclave pretreatment and cyanide mill and tailings disposal system. Responsible for permit preparation for BLM and Utah mining regulations; EPA and Utah water discharge regulations; EPA and Utah air regulations; BLM environmental assessment; as well as potable water, sanitary and solid waste permits. *Getty Minerals Resources Company - Mercur Canyon Project.*

Project Manager. Environmental reconnaissance; baseline studies; permits preparation and defense and subsequent permit modifications as required by operating conditions encountered for a major Nevada underground precious metal mine and cyanide mill. Responsible for all permits preparation, including BLM 3809 permit and NEPA analysis, Nevada air, solid waste and surface and ground-water discharge permits. *Sunshine Mining Company - 16-to-1 Mine.*

Project Manager. Responsible for conducting due diligence project and permits review for this major underground copper-silver project located within and adjacent to the Cabinet Mountains Wilderness. The work included permit and compliance review, reclamation plan review and environmental cash flow estimation from the time of the study through closure, reclamation and bond release. *Watts, Griffis and McQuat Limited for confidential client.*

EDUCATION AND PROFESSIONAL EXPERIENCE

Northern Illinois University - B.S. in Accounting and Finance
University of Idaho, School of Mines - Design of Small Scale Gold
and Silver Mines and Mills (Shortcourse)

University of Nevada, Mackay School of Mines - Fundamentals of Mining (Shortcourse)

Faculty Member for Colorado School of Mines Short courses:
"*Introduction to Gold and Silver for Miners, Prospectors and Investors*"
and "*Gold and Silver for Experienced Miners, Prospectors, Processors and Investors*".

Pintail Systems

LESLIE C. THOMPSON
Vice President - Research and Development

Education

University/ Graduate-Continuing Education	Program
Purdue University	Biology
OSHA 40 Hour HAZWOPER Certification	-
University of Colorado	instrumental analysis, statistics, genetics
American Chemical Society	Geochemistry of Groundwater - 40 hour
Society of Mining Engineers	Cyanide in the Environment - 24 hour
American Type Culture Collection	Freezing and Freeze-Drying of Microorganisms - 24 hr
American Type Culture Collection	Biotechnology Patent Workshops - 48 hour
University of Delaware	Bacteria Identification - 40 hour
ASSMR-SRK/USFS	Evaluation and Remediation of Acid Rock Drainage
ASSMR-Colorado School of Mines	Wetland Design for Mining Operations Short Course
American Type Culture Collection	Management of Cell Culture Collections-24 hour
Language Proficiency	French, German, Russian
U.S EPA Risk Reduction & Engineering Laboratory, Cinncinati	Invited Panelist/Industry Leader for Symposium on Industrial Application of Sulfate Reducing Bacteria

Ms. Thompson is a member of the American Chemical Society, the Society of Mining Engineers, the Metallurgical Society, the Society of Industrial Microbiologists, the Mining and Metallurgical Society of America, the Northwest Mining Association and the Society of Mineral Analysts.

Experience

Specialized in the development of innovative bioremediation processes for industrial and mining waste. Experience includes design and management of laboratory, field and research operations for process development. Background in project design, management, environmental assessment, cost engineering and bioremediation services/process research and development.

1991-Present **Pintail Systems, Inc.**
Vice President - Research & Development
Responsible for overall management of environmental research program, development of bioremediation services, oversight of field engineering, proposal development, and technical presentation/report preparation. Developed field bioremediation processes for cyanide detoxification in mine waste including ore, tailings and process solutions. Demonstrated development and application of bioremediation processes for control of acid rock drainage, heavy metal wastes, nitrates, complexed metal cyanides and petroleum hydrocarbons. Designed and engineered field remediation processes including bioculture production, application, *in Situ* remediation, nutrient formulation and packaging and field analytical support. Successful field remediation processes include detoxification of more than 5 million tons of contaminated spent ore at gold mines in the western U.S.

1981-1991 **Gold Fields Mining Corporation**

Microbiologist/Chemist

Responsible for design and construction of multiple assay laboratories, development of instrumental analysis support for gold exploration operations, and development of biogeochemical precious metal exploration programs. Integrated the first industry application of biogeochemical/geomicrobial field exploration and remote sensing exploration technology. Designed and directed geomicrobial research for sulfide and refractory ore processing and cyanide/nitrate remediation. Engineered and managed field tests of bioremediation processes for mine waste decontamination including detoxification of cyanide and nitrate in spent ore, tailings, waste rock, contaminated soil and groundwater. Project management included engineering design, monitoring well installation, bacteria production, soil sampling, construction, process application and site management.

1974-1981 **Shell Chemical Company**

Laboratory Shift Leader

Responsibilities included routine analytical support for manufacturing operations and environmental monitoring for pesticide manufacturing operation. Job functions consisted of development of instrumental analytical methods for manufacturing intermediates, raw materials, final products and soil, surface and groundwater samples. Responsible for supervision of 2-6 laboratory technicians or plant operators. Analytical specialization and expertise included Gas Chromatography, Infrared Spectroscopy, High Performace Liquid Chromatography, Differential Scanning Calorimetry, Thin Layer Chromatography, Atomic Absorption Spectrophotometry, gravimetric, titrimetric, distillation, extraction and process control analysis. Closely involved with research and development of pyrethroid generation of pesticides. Provided analytical support for environmental assessment and remediation.

Ms Thompson has taught several short courses and workshops on biotreatment processes, hazardous waste management, acid rock drainage evaluation and remediation, and biohydrometallurgy. Ms Thompson has authored or coauthored more than thirty publications of bioremediation technology.

Planera

BERNHARD E. STROM

Planera, Inc.
525 Spring Canyon Court
Fort Collins, Colorado 80525

PROFESSIONAL HISTORY

Planera, Inc.
ENSR Consulting and Engineering Corporation
Harvard Graduate School of Design
Colorado Springs City Planning Department

EDUCATION

M.C.R.P. (City and Regional Planning) Harvard University
B.S. (Urban Planning) Iowa State University

PROFESSIONAL AFFILIATIONS

American Planning Association
Urban Land Institute
Fort Collins, Colorado, Planning and Zoning Board
Former Colorado State Representative

TECHNICAL SPECIALTIES

Mr. Strom has 20 years of experience in:

* Socioeconomic Impact Assessment
* Transportation Studies
* Comprehensive Community Planning, Land Use Planning and Regulation
* Visual Resource Assessment
* Industrial Site Selection
* Community Noise Studies

REPRESENTATIVE PROJECT EXPERIENCE

* *City of Fort Collins - Rockwell Dam and Water Supply Project.* Human Resources discipline manager for a preliminary EA and scoping document for the proposed Rockwell Dam. Wild and Scenic River and wilderness issues were key project concerns.

* *U.S. Army COE - Spinney Mountain Reservoir EIS.* Prepared EIS sections dealing with human environment issues for proposed dam and reservoir project in central Colorado.

* *Forest Service - Homestake II Water Diversion EIS.* The proposed project entailed expansion of a transmountain water diversion project in the Holy Cross Wilderness in central Colorado.

* *Colorado-Ute Electric Association - Basalt-Carbondale Transmission Line.* Conducted analysis of visual, land use, and socioeconomic effects of the proposed transmission line in western Colorado's Roaring Fork Valley.

* *Forest Service and Carlota Copper Company - Carlota Copper Project EIS.* Discipline manager for noise and transportation studies for a third-party EIS evaluating the proposed development of an open pit copper mine project near Globe, Arizona. Key issue include high sensitivity to potential noise emissions because of proximity to both a small residential community and the Superstition Wilderness.

* *BLM and Round Mountain Gold Corp. - Round Mountain Mine EIS.* Discipline manager for visual resources and noise analysis for a third-party EIS addressing the effects of proposed modifications and a new mill at one of the world's largest heap leach gold mines. Computer assisted visual simulations were prepared to document previously approved, but not yet completed, expansion projects in addition to evaluating the likely effects of the current proposal. The historic mine had been incrementally expanded through a series of EA's; the latest proposal triggered a full EIS analysis.

* *Idaho Panhandle National Forests - Katka Peak EIS.* Discipline manager for visual resources, recreation, and roadless areas studies for an EIS analyzing the effects of a timber sale near Bonners Ferry, Idaho. A broad range of alternatives was studied to determine whether Forest Plan timber production goals could be achieved without sacrificing other resources, including a substantial roadless area, grizzly bear security habitat, and the popular Kootenai River rafting and canoeing opportunities. Visual simulations were prepared to help evaluate the scenic effects of timber production from a highly visible mountain face overlooking Bonners Ferry and popular tourist routes to Canada.

* *BLM and Atlas Minerals Corp. - Grassy Mountain Project EIS.* Discipline manager and principal investigator for human resources studies addressing socioeconomics, transportation, visual resources, recreation, and land use issues for a third party EIS assessing development of an open pit gold mine near Vale, Oregon. The proposed mine and associated road and transmission line corridors raised numerous social, economic and safety concerns, because of the location in an area with no recent experience with large scale mining. Key issues include boom-bust effects and risks from transport of hazardous chemicals on rural roads.

* *BLM and Barrick Goldstrike Mines, Inc. - Betze Project EIS.* Discipline Manager for noise, transportation, and visual resources studies for third party EIS addressing a major expansion of existing mining activity on the Carlin trend in Eureka County, Nevada. Key issues ranged from evaluation of appropriate visual mitigation strategies for existing and future disturbance in a remote area to consideration of cumulative traffic effects in Elko.

* *Southern Pacific Transportation Co. - Pacific Pipeline System.* Discipline manager for transportation, community noise, and socioeconomics studies for proponent's environmental assessment prepared for submittal to the California Public Utilities Commission. The proposed project is a common carrier pipeline designed to transport crude oil from the Gaviota area of Santa Barbara County to refineries in El Segundo and Long Beach. The project proposes to use Southern Pacific Railroad right of way for most of the route. Key issue include construction effects on traffic capacity of major urban thoroughfares, construction noise effects on residential neighborhoods and potential for growth inducement in the Los Angeles basin.

* *Forest Service and Westmont Mining, Inc. - Mt. Hamilton Project.* Human resources discipline manager. Prepared a socioeconomic, transportation, and recreation impact assessment pursuant to a Forest Service Environmental Assessment for a proposed gold mine and processing facility on the Humboldt National Forest near Ely, Nevada. Key issues included availability and condition of worker housing and cumulative socioeconomic effects from a resurgence of mining in the area concurrent with construction of a new state prison. Effects on Native American communities in the vicinity were also investigated.

* *BLM and Molycorp, Inc. - Guadalupe Mountain Tailings Disposal Facility.* Visual resources and noise task manager for a third-party EIS for a proposed 200-million ton tailings disposal facility near Questa, New Mexico. Visual and noise issues were particularly sensitive because of the project's proximity to the Rio Grande Wild and Scenic River and associated campground and recreation facilities.

* *Forest Service, Plumas Co. & Inca Minerals Corp. - Rich Gulch Gold Mine EA/EIR.* Managed human environment disciplines for preliminary studies leading to a third-party Joint Environmental Document fulfilling the requirements of a Forest Service EA and a California State EIR on the proposed gold mine project. Important issues were transportation safety, employment, community noise, and aesthetic effects of the proposed surface mine in the Feather River Canyon country of northern California.

* *Forest Service - Great Northern Mountain Ski Development.* Human resources discipline manager for development of work scopes for a Forest Service EIS including socioeconomic, transportation, land use, visual resources, and recreation studies. Proposed project was the Great Northern Mountain Ski Development and base area

residential facilities near Libby, Montana. Key issues included economic feasibility, grizzly bear and other wildlife habitat, and transportation.

* *BLM and Bond Gold Bullfrog, Inc. - Bullfrog North Underground Expansion Project.* Human resources discipline manager and principal investigator. Prepared analysis for a technical memorandum and relevant sections of a third party EA addressing socioeconomic, transportation, visual effects, cultural resources, and noise and vibration issues for a proposed underground expansion to an existing surface gold mine and milling operation. Project is located just east of Death Valley National Monument near Beatty, Nevada. Key visual concerns stemmed from proximity to the National Monument and National Register eligible ghost town of Rhyolite.

* *BLM and Gold Fields Mining Company - Mule Canyon Mine Project EA/EIS.* Transportation and socioeconomics discipline manager for a third-party BLM EA/EIS for a proposed gold mine near Battle Mountain Nevada. Project will include a surface mine, ore crushing, heap leach pads, gold extraction, and refining.

* *ECOS Corp. - TSD Site Selection Project.* Project manager for development and implementation of a site selection methodology for a full service commercial hazardous waste incinerator and landfill facility. Developed site criteria and employed environmental constraint mapping in progressively more detailed stages, beginning with the entire state of Washington and ultimately focusing on a select group of individual sites.

* *BLM and FMC Gold Company - County Line Project EA.* Human resources discipline manager and principal author of technical report and relevant EA sections addressing socioeconomic, transportation, land use, and recreation issues for proposed gold mine in Mineral and Nye Counties, Nevada. Key issues were housing availability for workers in Gabbs and Hawthorne and cumulative effects related to mining development and mission changes at the Hawthorne Army Ammunition Plant.

* *BLM and Bond Gold Bullfrog, Inc. - Bullfrog/Montgomery Shoshone Project.* Transportation, visual resources, and noise discipline manager for third-party BLM EA for proposed gold mine, mill, and heap leach operation. Project is located just east of Death Valley National Monument near Beatty, Nevada. Key visual concerns stemmed from proximity to the National Monument and the ghost town of Rhyolite.

* *City of Fort Collins - Rockwell Dam and Water Supply Project.* Human Resources discipline manager for a preliminary EA and scoping document for the proposed Rockwell Dam. Wild and Scenic River and wilderness issues were key project concerns.

* *Forest Service - Homestake II Water Diversion EIS.* Prepared EIS sections addressing socioeconomic effects drawing on a subcontractor's technical report. The proposed project

entailed expansion of a transmountain water diversion project in the Holy Cross Wilderness in central Colorado.

* *Chevron Shale Oil Co. - Clear Creek Shale Project.* Served as a consultant to the client on the quality and extent of human environment baseline studies required pursuant to Colorado State permits and preparation of a federal EIS. Also managed and prepared selected land use, visual resources, and recreation studies for baseline studies and permit applications.

* *BLM and Superior Oil Co. - Land Exchange and Oil Shale EIS.* Prepared land use, transportation, and selected socioeconomic components of a Draft EIS on proposed land exchange in the northern reaches off the Piceance Basin of Colorado.

PTI Environmental Services (PTI)

MICHAEL V. RUBY
Senior Environmental Chemist

Experience Summary

Mr. Michael Ruby has more than 10 years of experience in environmental chemistry and geochemistry, and in recent years has integrated geochemical analyses into specialized studies of transport, bioavailability, and source determination of lead, arsenic, cadmium, chromium, and zinc, especially originating from mining, milling, and smelting sites. Mr. Ruby has directed multi-disciplinary projects with emphasis in soil, sediment, and water quality issues, generally driven by human health risk assessment concerns. He has considerable experience in developing and implementing RI/FSs for sites with inorganic contamination of surface water and groundwater, soil, air, and sediments, and in designing and evaluating remedial strategies for such sites. Mr. Ruby has also provided technical support to litigation teams evaluating the sources and bioavailability of lead forms and apportioning lead sources in urban environments. In addition, Mr. Ruby was responsible for the design and construction of the PTI Boulder laboratory and continues to oversee its day-to-day operation.

Credentials

M.S., Physical Chemistry - Stanford University (1988)

B.A., Chemistry - University of California, San Diego (1984)

Hazardous Waste Operations and Emergency Response 40-hour training program; Hazardous Waste Operations Management and Supervisor 8-hour training program; American Chemical Society; Society for Environmental Geochemistry and Health; Society of Environmental Toxicology and Chemistry; University of Colorado Research Association

Key Projects

Managed a comprehensive study to evaluate human health effects from lead, cadmium, and arsenic in residential soils during the National Zinc Superfund RI/FS in Bartlesville, OK. Site-specific studies included speciation, bioaccessibility, and bioavailability of lead, cadmium, and zinc; soil-to-dust transfer coefficients; distribution of smelter waste types (fugitive emissions, slag, sintering residues) in the community; and sources of lead in house dust and residents' blood.

Managed bench- and pilot-scale treatability studies to evaluate *in situ* phosphate amendment as a method for reducing lead bioavailability from soil. Study results will be used to support a novel soil lead remediation method, potentially resulting in considerable cost savings to the PRP group at the site.

Managed a project that developed groundwater proection standards for soil at a former pesticide formulation facility. Contaminant leachability from soil was determined through laboratory experiments, and groundwater transport modeling was used to establish soil contaminant concentrations that would be protective of groundwater quality at a downgradient point of compliance.

Managed a project that resulted in the design of two novel remediation technologies—the agricultural ecosystem and co-composting—for toxaphene remediation in soil. The co-composting technology has been implemented in a field-scale treatability study designed to optimize the operating parameters for full-scale site application.

Managed a bench-scale treatability study to evaluate the efficacy of soil amendments—including phosphate, iron, phosphate and iron, and biosolids—for reducing the solubility and bioavailability of lead, cadmium, and arsenic in soil. Study results will be used to select appropriate amendments for field-scale testing on residential soils at a lead smelter site.

Managed a multi-disciplinary study designed to apportion lead-bearing tailings in creek channel sediments and overbank deposits among multiple PRPs using statistical evaluation of geochemical tracers.

Managed a multi-disciplinary team evaluating the transport and fate of DDT, toxaphene, parathion, and lindane at a pesticide formulation plant in Georgia.

Evaluated metals source apportionment methods for soils at a railyard adjacent to the client's brass and iron foundry. Results indicated that site-specific conditions precluded the railyard owner's consultant from developing a defensible method of determining the foundry's contribution of metals to railyard soils.

Designed a comprehensive study to evaluate geochemical and biological stabilization of chromium at a former tannery in Michigan. The study was designed to establish the long-term stability of chromium in support of a reduction in the volume of soils and sediments to be remediated.

Managed two investigations that combined arsenic speciation studies with arsenic bioavailability determinations for soil at a historical zinc smelter and a pesticide production facility, respectively. These studies were used to justify higher soil remediation goals for arsenic in soil, while ensuring protection of public health.

Developed and published an *in vitro* screening method, verified with an *in vivo* feeding study in Sprague-Dawley rats, to estimate lead bioavailability from soils and mine wastes.

Managed a project that resulted in development of an *in vitro* method—termed the Physiologically Based Bioavailability Test (PBBT)—and application of the test to lead bioavailability estimation from soils, mine wastes (waste rock, tailings, and slag), industrial process wastes, and recycled hazardous waste.

Managed the design and implementation of a microcosm study to evaluate biological degradation of lindane, parathion, ethylbenzene, and benzene in a Florida aquifer. Results were used to predict contaminant transport in a groundwater model and to optimize selection of appropriate remedial technologies.

Managed a comprehensive project that resulted in development of an *in vitro* screening method, which replicates gastrointestinal chemistry and function, to estimate arsenic bioavailability. The *in vitro* test was validated using bioavailability studies in New Zealand white rabbits and Cynomolgus monkeys.

Responsible for the design, implementation, and publication of a study to examine the bioavailability of lead and arsenic from mine-waste-impacted soils in Montana. Study results were used to support a bioavailability adjustment for lead in soil, resulting in higher remediation goals for lead that are still protective of human health.

Developed a comprehensive plan to examine the environmental transport and fate of lead at a television manufacturing facility in Ohio.

Managed a study that examined the arsenic mineralogy of smelter-impacted soils and partitioning of the observed arsenic forms between the potential source materials.

Managed a study to evaluate the composition and mineral speciation of arsenic in house dust. In addition, probability distributions of arsenic bioavailability values for soil and house dust were generated for input to a probabilistic arsenic risk assessment.

Conducted lead mineralogy studies and bioavailability assessments at mining sites in Kansas, New Mexico, and Texas, and at urban sites in Michigan, Texas, and Mississippi.

Responsible for the design, implementation, and publication of a study on the dissolution kinetics of lead from soils and pure lead minerals under physiological conditions. Study results indicated that dissolution kinetics will limit lead bioavailability from mine-waste materials in Butte, Montana.

Responsible for the design, implementation, and publication of a study to evaluate the mineralogy of mine waste in relation to lead bioavailability at a site in Montana.

Assisted in data analysis and validation of inorganic data for EPA contracts.

Participated in the study and publication of PCP transport and fate, specifically biodegradation, at a wood-treating site in Florida.

Conducted research on pesticides applied to soils to determine irreversible adsorption and chemical fluxes from impacted soils.

Assisted in data analysis and validation of volatile organic, semivolatile organic, and pesticide/PCB data for EPA contracts.

Developed a litigation support strategy for a mining industry client in a Superfund cost recovery action.

Studied the environmental stability and bioaccessibility of lead in slag in support of a litigation team.

Developed and conducted a study to determine the sources of lead-bearing tailings materials and to apportion responsibility according to the relative contribution of each PRP.

Evaluated methods to apportion between automobile tailpipe and paint sources of lead in an urban environment.

Assessed the sources of lead to residential drinking water supplies in support of a litigation effort.

Selected Publications

Kennedy, S.K., G.S. Casuccio, R.J. Lee, G.A. Slifka, and M.V. Ruby. (In press). Microbeam analysis of heavy element phases in polished sections of particulate material—An improved insight into origin and bioavailability. In: Sampling environmental media, J.H. Morgan (Ed.). American Society for Testing and Materials, Philadelphia, PA.

Boyce, C.P., M.K. Butcher, D.M. Nelson, R.A. Schoof, and M.V. Ruby. (In press). Relationship between outdoor soil and indoor dust concentrations of arsenic, cadmium, lead, and zinc at a zinc smelter site. Environ. Geochem. Health.

Davis, A., M.V. Ruby, and P.D. Bergstrom. 1994. Factors controlling lead bioavailability in the Butte mining district, Montana, U.S.A. Environ. Geochem. Health. 16(3/4):147–158.

Davis, A., J. Campbell, C. Gilbert, M.V. Ruby, M. Bennett, and S. Tobin. 1994. Attenuation and biodegradation of chlorophenols in ground water at a former wood treating facility. Ground Water 32(2)248–257.

Link, T.E., M.V. Ruby, A. Davis, and A. Nicholson. Soil mineralogy by microprobe: An interlaboratory comparison. Environ. Sci. Technol. 28(5):985–988.

Ruby, M.V., A. Davis, and A. Nicholson. 1994. *In situ* formation of lead phosphates in soils as a method for immobilization of lead. Environ. Sci. Technol. 28(4)646–654.

Ruby, M.V., A. Davis, T.E. Link, R. Schoof, R.L. Chaney, G.B. Freeman, and P. Bergstrom. 1994. Development of an *in vitro* screening test to evaluate the *in vivo* solubility of ingested mine-waste lead. Environ. Sci. Technol. 27(13)2870–2877.

Davis, A., J.W. Drexler, M.V. Ruby, and A. Nicholson. 1993. Micromineralogy of mine wastes in relation to lead bioavailability, Butte, Montana. Environ. Sci. Technol. 27(7)1415–1425.

Freeman, G.B., J.D. Johnson, J.M. Killinger, S.C. Liao, A.O. Davis, M.V. Ruby, R.L. Chaney, S.C. Lovre, and P.D. Bergstrom. 1993. Bioavailability of arsenic in soil impacted by smelter activities following oral administration in rabbits. Fund. Appl. Toxicol. 21:83–88.

Davis, A., M.V. Ruby, and P. Bergstrom. 1992. The bioavailability of arsenic and lead in soils from the Butte mining district. Environ. Sci. Technol. 26(3)461–468.

Freeman, G., J. Johnson, J. Killinger, S. Liao, P. Feder, M.V. Ruby, A. Davis, R. Chaney, S. Lovre, and P. Bergstrom. 1992. Relative bioavailability of lead from mining waste soil in rats. Fund. Appl. Toxicol. 19:388–398.

Ruby, M.V., A. Davis, J.H. Kempton, J.W. Drexler, and P. Bergstrom. 1992. Lead bioavailability: dissolution kinetics under simulated gastric conditions. Environ. Sci. Technol. 26(6)1242–1247.

Davis, A., M.V. Ruby, and P. Bergstrom. 1991. Geochemical controls on the bioavailability of lead from mining waste impacted soils. In: Proc. of the Hazardous Materials Conference. Hazardous Materials control Institute, Greenbelt, MD.

Hemphill, C., M.V. Ruby, B. Beck, A. Davis, and P. Bergstrom. 1991. The bioavailability of lead in mining wastes: Physical/chemical considerations. Chem. Spec. Bioavail. 3(3/4)135–148.

Publications Under Review

Ruby, M.V., A. Davis, R. Schoof, S. Eberle, and C. Sellstone. An improved physiologically based bioaccessibility test for lead and arsenic. Submitted to Environ. Sci. Technol.

Freeman, G.B., R.A. Schoof, M.V. Ruby, A.O. Davis, S.C. Liao, and P.D. Bergstrom. Bioavailability of arsenic in soil and house dust impacted by smelter activities following oral administration in Cynomolgus monkeys. Submitted to Fundam. Appl. Toxicol.

Ruby, M.V., T. Link, S.K. Kennedy, and W. Shields. Source apportionment of lead and cadmium in the environment near a historical zinc smelter. Submitted to Environ. Sci. Technol.

Davis, A., M.V. Ruby, M. Bloom, R. Schoof, G. Freeman, and P.D. Bergstrom. Mineralogic constraints on the bioavailability of arsenic in smelter-impacted soils. Submitted to Environ. Sci. Technol.

ROSALIND A. SCHOOF
Principal Toxicologist

Experience Summary

Dr. Rosalind Schoof is a board-certified toxicologist with 18 years of professional experience in assessing human health effects from toxic substances. She has coordinated and reviewed risk assessments for CERCLA and RCRA sites with a wide variety of contaminants and settings, and she has provided critical evaluations of risk assessment procedural guidance from both programs. Dr. Schoof has developed position papers addressing methods for assessing risks from exposure to arsenic, cadmium, and lead at mining sites, including appropriate adjustments to reflect the reduced bioavailability of metals in mining wastes. Other kinds of sites evaluated include wood-treating facilities, military installations, petroleum bulk fuel facilities, hazardous and municipal waste landfills, and resource recovery facilities. As study director for toxicology studies at a pharmaceutical company, she was responsible for coordinating all aspects of acute, chronic, carcinogenic, and genetic toxicity studies, including study design, evaluation of in-life data, clinical pathology, pathology, and statistical guidance.

Credentials

Ph.D., Toxicology - University of Cincinnati (1982)

B.A., Molecular Biology - Wellesley College (1975)

Diplomate, American Board of Toxicology (1986)

Society of Toxicology; American College of Toxicology; Pacific Northwest Association of Toxicologists; Society for Risk Analysis; Society for Environmental Geochemistry and Health

Key Projects

Providing toxicological support on a PCB risk assessment sensitivity analysis project. Identifying those components of risk assessment methodology that have the greatest influence on PCB cleanup levels.

Managing a multisite general risk assessment support contract for a major corporate client. In addition to providing risk assessment support for specific sites, responsibilities include ensuring that risk assessment strategies and positions are consistent from site to site. Risk assessment strategies are coordinated with litigation strategies. Presentations are also made to EPA and state staff on behalf of the client.

Managing a bioavailability research program for arsenic and lead from soils contaminated by mining wastes in which mineralogic analyses and *in vitro* screening studies are being used to help interpret the results of animal studies.

Managed human health risk assessment tasks for work plan, remedial investigation, and feasibility study of a former zinc smelter site in Bartlesville, Oklahoma. Planned for collection of site-specific data to fill gaps in EPA's baseline human health risk assessment, including paired soil and indoor dust samples, hot spot delineation, and a bioavailability study of cadmium and lead in soil. Directed development of revised remediation goals for arsenic, cadmium, and lead using site-specific data and preparation of position papers supporting the recommended goals. Presented plans and results to EPA and state staff and at public meetings.

Directed an investigation of arsenic intake in the diets of people living in areas of Taiwan with elevated arsenic concentrations in artesian well water. Samples of rice and yams were collected in Taiwan and analyzed in the United States for inorganic and organic arsenic concentrations. The results showed that arsenic intake from the diet was much higher than assumed by EPA and were used to support recalculations of the oral arsenic toxicity values.

Managed preparation of a position paper describing the proper methods for evaluating exposures to lead and arsenic from mining wastes in residential soils in Butte, Montana. Issues included evaluation of the uncertainties associated with EPA's oral carcinogenicity assessment for arsenic, bioavailability of lead and arsenic in soils, and discussion of appropriate ways to apply the uptake biokinetic model and community blood-lead studies to assessments of lead exposures. Comments were also prepared on the baseline risk assessment and preliminary remedial goals.

Prepared documents describing the proper methods to evaluate risks from flue dust and mining wastes contaminated with arsenic, lead, and cadmium for several operable units in Anaconda, Montana. Evaluations considered residential, occupational, and recreational exposures. Baseline risk assessments and preliminary remediation goals were also reviewed and critiqued.

Prepared documents describing the proper methods to evaluate risks from groundwater and surface water contaminated with arsenic, lead, cadmium, and other metals released as mining by-products at several operable units in Butte, Montana. Also critiqued preliminary baseline risk assessments from EPA and state agencies.

Assisted in preparation of a document describing the proper methods of evaluating human health risks associated with recreational exposures to arsenic, cadmium, and lead in sediments at a reservoir in Montana.

Advised client of best methods for assessment of lead exposures at a historic mining site in the Rocky Mountains. Described available data and appropriate methods for comparing the bioavailability of lead from soil, slag, mining wastes, and tailings. Critiques were provided for community blood-lead studies and the application of the uptake biokinetic model to assessment of lead exposures at the site.

Served as project manager for technical enforcement support oversight activities at several U.S. Navy NPL sites in Washington. Provided human health risk assessment guidance and coordinated review of all aspects of remedial investigation work plans and reports. Contaminants included chlorinated hydrocarbons, solvents, metals, and fuels. Primary exposure pathways included groundwater, surface water, and marine organisms exposed to contaminated sediments.

Managed preparation of documents describing the proper methods of evaluating human health and ecological risks from PCP, PAH, and dioxin contamination at a pole-treating plant in Butte, Montana. Assessed risks from exposures to soil, groundwater, surface water, and air. Also critiqued a state preliminary baseline risk assessment and preliminary remediation goals.

Performed a risk assessment for ocean disposal of dioxin-contaminated sediments from Grays Harbor, Washington. Coordinated with other agencies to develop exposure assessment methods acceptable to EPA and the state. Evaluated sources of uncertainty.

Assisted in preparing a work plan and risk assessment to assess risks and develop cleanup levels for benzene-contaminated groundwater from leakage of petroleum products at a transfer station in Alaska.

Determined technical requirements and critically reviewed risk assessment and proposed groundwater cleanup levels for a gasoline leak from an underground storage tank in Alaska. Provided guidance for risk management strategy.

Prepared technical review comments on draft reports assessing the risks associated with exposure to arsenic, cadmium, and lead in mining waste transported to residential areas by stream flooding at a site in Utah.

Prepared a human and environmental assessment work plan for a RCRA facility investigation of a petroleum refinery in the western United States. Key contaminants included BTEX, PAH, and chlorinated hydrocarbons.

Provided human health risk assessment guidance and work plan review for CERCLA and RCRA investigations of a federal facility in Oregon contaminated with munitions.

Evaluated potential human health impacts of cleanup alternatives for an EIS for the Model Toxics Control Act. Participated in developing the risk-based alternative.

Updated and revised a human health risk assessment for an EIS on the application of herbicides to Washington lakes.

Performed public health and risk analysis for a municipal incinerator as part of an EIS on waste reduction, recycling, and disposal alternatives for Seattle, Washington. Assessed risks from stack emissions of metals, dioxins, and other organic compounds. Presented methods and results to local, state, and federal officials, environmental groups, the public, and a peer review committee.

Performed a preliminary risk assessment for the development of a hazardous waste incinerator for a chemical company in New Jersey.

Provided extensive peer review comments on methods and results of a risk assessment on a hazardous waste incinerator for a chemical company in Kentucky.

Developed procedures and preliminary assessments for a municipal incinerator planned by a Native American tribe in Washington.

Participated in planning and design of a study of methylmercury concentrations in hair of native Alaskans subsisting on fish and sea mammals in Nome, Alaska.

Assisted in a preliminary assessment of risks from metals and pesticides in fill material used during construction of a road in Alaska.

Participated in indicator chemical selection and provided toxicology support for risk assessments at several hazardous waste sites. Contaminants included ordnance and explosive material, PCB, chlorinated hydrocarbons, BTEX, PAH, lead, and other metals.

Participated in the development of cleanup standards for lead, BTEX, and PCB at sites in California, Oregon, and Washington. Sites were slated for various planned uses, including housing developments, a museum, playground, marina, and various commercial concerns.

Participated in peer review of a risk assessment for a large municipal landfill near Seattle, Washington.

Provided toxicology support for the risk assessment for final cleanup operations at a former smelter site in Tacoma, Washington.

Provided technical support for a PRP in litigation to negotiate a *de minimis* settlement at the Commencement Bay CERCLA site, Washington.

Designed, executed, and reported the results of toxicity studies in rodents, dogs, and monkeys, including acute, subchronic, chronic, and carcinogenicity studies.

Revised standard operating procedures for all toxicological laboratory studies for a major pharmaceutical company to comply with FDA Good Laboratory Practices.

Participated in interdivisional teams coordinating preclinical research and development projects for new drugs, including reproductive hormones, immunomodulatory drugs, and H_2 blockers.

Participated in efforts to develop test methods to determine effects on humans and the environment from toxic substances prior to the enactment of the TSCA. Managed projects to compile, review, and evaluate test methods.

Responsible for developing the implementation strategy for Section 4 of TSCA.

Managed development of a database to model and simulate structure-activity relationships of carcinogens and mutagens.

Wrote a review of atmospheric sulfates used for many years by EPA as an issue paper and used in courses at the Harvard School of Public Health.

Participated in a field study of the effects of sulfur oxide air pollution on the growth of lichens in the Ohio River Valley.

Selected Publications

G.B. Freeman, J.D. Johnson, S.C.Liao, P.I. Feder, A.O. Davis, M.V. Ruby, R.A. Schoof, R.L. Chaney, and P.D. Bergstrom. 1994. Absolute bioavailability of lead acetate and mining waste lead in rats. Toxicology. 91:151-163.

Schoof, R.A., L.Y. Yost, B. Beck, and P. Valberg. 1994. Recalculation of the oral arsenic reference dose and cancer slope factor using revised assumptions of inorganic arsenic intake from food. Toxicologist 14(1) Abstract 51:36.

Yost, L.J., and R.A. Schoof. 1993. Implications of the methylation status of arsenic in home-grown vegetables for risk assessment. Book of Posters: Society for Environmental Geochemistry and Health International Conference on Arsenic Exposure and Health Effects, July 28, 1993, New Orleans, LA.

Schoof, R., M.J. Steele, C. Petito Boyce, and C.G. Evans. 1993. Assessing the validity of lead bioavailability estimates from animal studies. Toxicologist 13(1) Abstract 478:141.

Petito Boyce, C., C.E. Evans, and R.A. Schoof. 1992. Impacts of recent developments in assessing toxicity and exposure on risk assessment for arsenic carcinogenicity. Toxicologist 12(1) Abstract 933: 246.

Davis, A., M.V. Ruby, and R. Schoof. 1992. Comments on "Lead, cadmium, and zinc contamination of Aspen garden soils and vegetation," by D.Y. Boon and P.N. Saltanpow. J. Environ. Qual. 21:82-86, 509-510.

Schoof, R.A., C. Petito Boyce, and S.G. Whittaker. 1992. Assessing the severity of carcinogenic health effects. Toxicologist 12(1) Abstract 290:94.

Steele, M.J., S.G. Whittaker, and R.A. Schoof. 1992. The impact of assumptions regarding metal concentrations in soil and dust on setting remedial objectives. In: Risk Assessment/Management Issues in the Environmental Planning of Mines. D. Van Zyl, M. Koval, and T.M. Li (eds.) Society for Mining, Metallurgy and Exploration, Littleton, CO.

Yost, L.Y., R.A. Schoof, C.E. Evans, and D.M. Nelson. 1992. Human health risk assessment for a former wood treatment plan. Presented at the 13th Annual Meeting of the Society of Environmental Toxicology and Chemistry, November 8-12, Cincinnati, OH.

Katz, L.B., R.A. Schoof, and D.A. Shriver. 1987. Use of a five-day test to predict the long-term effects of gastric antisecretory agents on serum gastrin in rats. J. Pharmacological Methods 18(4) 275-282.

Schoof, R.A., and C.S. Baxter. 1986. Topical application of a tumor promoter induces proliferation of an adherent cell population in murine spleen. Int. J. Immunopharm. 8:455-462.

Hahn, D.W., N. Hetyei, L. Beck, J.L. McGuire, and R.A. Schoof. 1985. Pharmacology and toxicology studies with microencapsulated norgestimate as a long acting injectable contraceptive. Adv. Contraception 2:235-236.

Baxter, C.S., R.A. Schoof, and A.T. Lawrence. 1984. Interaction of tumor promoting agents with immunofunctional cells *in vitro* and *in vivo*. International Agency for Research on Cancer Scientific Publications, No. 56.

Schoof, R.A., and C.S. Baxter. 1982. Splenic leukocyte proliferation following *in vivo* treatment with phorbolesters. In: Proc. of the NATO Advanced Study Institute on Immunotoxicology, Wolfville, Nova Scotia.

Schoof, R.A., and C.S. Baxter. 1982. Stimulation of murine splenic lymphocytes after skin painting with a tumor promoter. Toxicologist 2(1) Abstract 322:91.

Schoof, R.A. 1974. Atmospheric sulfates: a review. Publication No. RPTR-75-1. New England Consortium on Environmental Protection, Regional Environmental Program.

YVETTE WIEDER LOWNEY, M.P.H.
Senior Toxicologist

Experience Summary

Ms. Yvette Wieder Lowney has 15 years of professional toxicology and technical project management experience, specializing in human health risk assessment, with special focus on evaluating health effects associated with exposure to metals at mining, milling, and smelting sites, and with exposure to organic contaminants from riverine environments. Ms. Lowney has conducted health hazard evaluations for exposures to contaminated foods, water, and commercial products, and drafted and enforced waste discharge requirements for a California regulatory body charged with protecting water quality in San Francisco Bay. In addition to her broad-based technical background, Ms. Lowney has managed a branch consulting office, with responsibility for office staffing, project administration and budget oversight, career development of technical staff, and client development and representation.

Credentials

Masters in Public Health, Environmental Health/Toxicology - University of California at Berkeley (1986)

B.A., Molecular, Cellular, and Developmental Biology - University of Colorado at Boulder (1982)

Society for Risk Analysis, Rocky Mountain Chapter, President

Colorado Hazardous Waste Management Society

Key Projects

Prepared scoping documents outlining appropriate risk assessment procedures for two operable units at the Anaconda Smelter NPL site in Montana. Investigated current toxicological and regulatory status of contaminants of concern.

Prepared a risk assessment for a site with potential industrial contamination, including determination of contaminants of concern, elucidation of appropriate exposure pathways, and performance of a quantitative health evaluation of existing conditions. Specific issues of concern included dietary exposure from ingestion of contaminated fish, wildlife, or drinking water; and childhood exposures from contaminated breast milk or soil.

Managed project and prepared detailed technical comments on the public health risk assessment portion of a feasibility study for an NPL site in Montana. Major areas of comment focused on exposure scenarios, toxicity evaluation of various metals, and the soil cleanup levels selected for remediation. Developed alternative exposure assumptions and toxicity parameters, as well as health-based soil cleanup levels, for lead and arsenic at the site.

Prepared a report reviewing currently available data characterizing the neurological effects associated with pre- and postnatal lead exposures. Attention focused on age-specific differences in sensitivity and exposures to environmental lead. Evaluated literature in light of considerations for developing cleanup levels for sites with lead-contaminated soils.

Managed project and prepared the Baseline Public Health and Environmental Risk Assessment for an NPL site in EPA Region VI. Contaminants of concern at the site included cyanide and heavy metals. Evaluated pathways of exposure, including ingestion of contaminated water or soil, and inhalation of fugitive dusts.

Proposed health-based soil cleanup levels for an NPL site in Utah. Contaminants of concern at the site were arsenic, cadmium, and lead. The proposed cleanup levels were established based on possible soil ingestion or dust inhalation exposures.

Provided detailed critique of risk assessment documents for a mining and milling site in the western U.S. Evaluated alternative assumptions regarding soil ingestion rates and properties of arsenic and lead at mining and milling sites, as well as conducting a thorough review and interpretation of the literature regarding the impact of these contaminants on exposed populations.

Managed a project to review and critique an Endangerment Assessment for an NPL site near Anaconda, MT. Specific attention was given to evaluation of exposure and toxicity parameters, and risk estimates were recalculated incorporating updated parameters. Primary contaminants of concern included arsenic, cadmium, lead, and copper.

Provided critical review of a draft proposal for a methodology to be used in the determination of the impact of environmental lead on human blood lead and human health.

Provided toxicological information and evaluation for contaminants of concern at a wood-preserving plant in the southern U.S.

Managed the performance of a detailed risk assessment for human populations exposed to PCBs from the Hudson River. The evaluation include elucidation of the exposed population, exposure pathways, performance of a quantitative health evaluation, and a thorough discussion of limitations and uncertainties associated with all phases of the assessment.

Managed a human health evaluation for a site where waste rocket fuel had impacted groundwater.

Managed a program to analyze emerging regulations and their impact on metals-contaminated sites.

Conducted specialized toxicological risk assessments of chemically contaminated seafood. Provided analysis of data and, when appropriate, developed consumption guidelines to warn the public of possible hazard. Worked with regulatory agencies and industry in studying potential contamination of waterways and foodstuffs, and determining appropriate environmental monitoring. Also prepared scientific reports that served as a technical basis for the development of health policy and regulations.

Designed and implemented a program to protect young children from exposure to toxicants in schools. Developed original criteria for evaluation of products; consulted with legislators, manufacturers, and educators; evaluated epidemiological and toxicological literature for evidence of harmful effects from chemicals; developed health education curricula; and conducted workshops for school personnel and artists around the state of California.

Evaluated the potential health risks associated with the exposure of the public to toxicants in water. Wrote document for the California legislature that discussed public health risks from exposure to drinking water contaminants. Conducted field research, including collection of environmental samples and biological specimens, to determine body burdens of pesticides and industrial chemicals.

Selected Publications

Lowney, Y., and B. Beck. 1990. Factors affecting selecting of an appropriate target population and soil cleanup level for lead. Poster presented at the conference on similarities and differences between children and adults: Implications for risk assessment, sponsored by the International Life Sciences Institute and the U.S. Environmental Protection Agency. Hunt Valley, MD, November 20–22.

Karam, H., B. Beck, and Y. Lowney. 1990. Evaluation of two methods to determine cleanup levels for lead in soil. Presented at the 4th Annual Exhibition and Conference of the Colorado Hazardous Waste Management Society, October 18–19, 1990, Denver, Colorado. Sponsored by the Colorado Hazardous Waste Management Society.

Fan, A., Y. Wieder, and M. DiBartolomeis. 1990. Human health implications of dietary selenium intake. Toxicologist 10(1):156.

Wieder, Y., G. Pollock, and I. Uhaa. 1989. Dioxin in fish from the Sacramento River: A health assessment. Poster presented at the 14th Annual Conference of the National Association of Environmental Professionals, Lake Tahoe, Nevada, June.

Uhaa, I., G. Pollock, Y. Wieder, A. Fan, and R. Cook. 1990. Potential health risk from consumption of contaminated fish: Dioxin contamination of the upper Sacramento River, California. J. Am. Publ. Hlth. Assn.

Pollock, G., Y. Wieder, and I. Uhaa. 1989. Factors involved in human health based study design of chemical contamination of fish: California Department of Health Services Study of Southern California. In: Proceedings of the National Marine Fisheries Service.

Pollock, G., Y. Wieder, I. Uhaa, and A. Fan. June 1989. Risk assessment of dioxins in fish. California Department of Health Services, Sacramento.

Schafer & Associates

Lorraine H. Filipek, Ph.D. RESUME

RESPONSIBILITIES:

Principal of Schafer and Associates, Denver. Oversees a variety of international mining projects, permit submittals, and research and development assignments. Specializes in geochemistry, waste characterization, constructed wetlands, international environmental assessments, pit-water physical and chemical modeling, solute transport modeling, soil investigations, and oceanography.

PROFESSIONAL REGISTRATION:

Certified Environmental Manager, Nevada

EDUCATION:

1965-1969	University of Michigan B.S. Biophysics
1972-1974	Johns Hopkins University M.A. Physical Oceanography
1975-1977	University of Michigan Environmental Health Studies
1977-1979	University of Michigan Ph.D. Chemical Oceanography

PROFESSIONAL COURSES:

1984	Groundwater Solute-Transport Modeling (10-day USGS course)
1985	Advanced Solute-Transport Modeling (10-day USGS course)
1993	Nevada Environmental Manager Training (4-day course)
1993	MSHA Health and Safety Refresher (also 1991, 1992)

PROFESSIONAL EXPERIENCE:

Project/Organization Management: Successfully managed projects dealing with international mining services, hazardous waste assessment, environmental audits and assessments, water treatment, mine permitting and closure, environmental monitoring, and environmental and mineral resources research. Managed government science organizations and delivered educational short courses and expert-witness testimony.

Mining Services: Project manager and/or lead geoscientist for a variety of mining projects including multi-contractor environmental assessments and impact evaluations for mining facilities in the United States, Panama, and Argentina; prediction, control, and remediation of AMD; design of constructed wetlands to treat AMD and cyanide tailing solutions; reclamation of open pits, waste rock, heap leach, and tailing sites; and land application of cyanide barren solutions. Developed geochemical models to determine source, flow path, and the ability of soil to attenuate seepage from tailing facilities. Co-designed a submerged tailing facility to mitigate AMD with minimal hydraulic head. Developed and reviewed development of numerical-flow and solute-transport models, including a model of the interaction of a tailing facility with a saline aquifer/freshwater river system in Bolivia. Designed water monitoring plans and Quality Assurance Project Plans for surface- and ground-water quality.

PROFESSIONAL EXPERIENCE - continued

Research and Assessment: Project manager for a variety of environmental and mineral resource projects including evaluation of phosphate addition to neutralize and inhibit AMD in an open pit; developing a numerical flow, heat, and solute transport model to evaluate the role of basin-wide flow in the formation of lead-zinc deposits; developing a model of metal migration through a wetland overlying a massive sulfide deposit; integrating soil geochemistry, ground-water flow, and geophysical information to produce a geochemical mineral assessment of bedrock covered by glacial overburden in Wisconsin; and conducting other research on water-rock and metal-organic interactions in the surficial environment.

Government Research Management: As Chief of the Branch of Geochemistry, U.S. Geological Survey, successfully managed 230 people involved in over 30 research, assessment, and technical support projects including environmental and mineral resource investigations, research on new chemical analytical techniques and chemical analytical support (about 40,000 samples per year) for 13 branches. As Associate Chief of the Branch of Coal Geology, managed 25 scientists involved in energy environmental research, assessment and technical support projects. Developed interdisciplinary research program on prediction, mitigation, and remediation of coal acid mine drainage in cooperation with the U.S. Bureau of Mines, the Office of Surface Mining, and state regulatory agencies. As Deputy Chief for Geochemistry and Environmental Activities in the Office of Mineral Resources, coordinated interactions between the U.S. Geological Survey and other agencies concerning environmental and geochemical research and development. Inter-agency projects included selenium geochemistry in the Kesterson Reservoir (CA) with the US Bureau of Reclamation and arsenic geochemistry at the Whitewood Creek (SD) Superfund site.

Education: Developed or co-developed and delivered a number of professional short courses on geochemical principles, constructed wetlands, and active water treatment methods.

Professional Activities:
Professional improvement maintained through active involvement in professional societies (Society of Economic Geologists, American Geophysical Union, Geological Society of America, Society for Sedimentary Geology, Denver Coal Club, Association for Women Geoscientists). Vice President of the Board of Directors, Genesee Water and Sanitation District. Authored more than 50 articles, book chapters, and presentations in professional publications and symposium proceedings.

APPENDIX B

EXISTING AND FUTURE LAND USE CONSIDERATIONS

Appendix B

Existing and Future Land Use Considerations

1.0 EXISTING LAND USE

The Town of Rico lies in the narrow Dolores River valley, flanked by steep, mountainous terrain on both the east and west. The developed portion of Rico lies in a small wide spot in the valley at the confluence of Silver Creek with the Dolores. The Dolores River is a major feature of the community, providing a historic focus as well as recreational and natural open space opportunities in counterpoint to the rugged mountain setting. Rico's town limits extend about 1.25 miles north to south; the core of the town is about 0.4 mile east to west, although claim blocks annexed on the northwest and southeast extend the boundaries by up to 0.33 mile beyond the historical core boundaries in both directions.

Rico is a predominantly residential community in 1995. Slightly less than 34 acres are considered developed; almost 84 percent of the developed acreage is occupied by single family residences (see Section 1.0, Figure 1-1). There are an estimated 147 single family homes that are either occupied or sound enough that they could be habitable with a reasonable investment of time and/or money (Heil 1995). In addition, there are three townhouse residential units in one modern complex.

About six percent of Rico's developed acreage is commercial, all of it along the main street, Glasgow Avenue (State Highway 145). Much of the commercial development comprises historic structures, some of which are benefiting from substantial renovation. Several of the commercial structures are vacant or minimally used for storage. There are no operating retail facilities in Rico at this time, although a gas station/convenience store that operated until recently, is for sale and still apparently in sound condition. An additional three percent of the developed acreage is occupied by a hotel, a motel, and a bed & breakfast operation. Five percent of the developed portion of Rico is in public or quasi-public uses, including public buildings, the post office, three churches, and a lodge. Finally, there is a small public park adjacent to the community center (the former school).

Most existing development in Rico occurs within the historic core of the town, which is platted in a grid pattern with no regard to terrain. The typical block contains 40 lots, each 25 feet wide by 100 feet deep. A few of these small, narrow lots are developed individually, although many have been aggregated into larger parcels. The current town zoning ordinance (Ordinance No. 274, as amended) requires a minimum lot width of 50 feet except in the downtown Commercial Historical District. Two residential subdivisions have been platted recently, one on the northeast edge of town and one on the south end of the old grid. The new lots range from about one-third of an acre to over two acres, substantially larger than the traditional lots in the community.

The developed portion of Rico, not including streets and roads, occupies only 10 to 15 percent of the incorporated area. The undeveloped portions include several parcels within the historic core of the community, although much of the undeveloped area is river bottom lands or steep slopes on the fringes of town. Areas most amenable to future development are likely to be along the river valley south of town and, perhaps, on narrow benches above the town on the east and west flanks of the valley. Planners and engineers for the town and for private landowners are investigating potentially developable areas in greater depth. Additional information on their efforts is expected in the fall of 1995. A River Corridor Plan evaluating river features and opportunities is also in process, supported by a demonstration grant from Great Outdoors Colorado.

2.0 FUTURE LAND USE

Future land use in the project area is evolving through a series of public and private initiatives currently being carried forward by the town of Rico and private land owners with the assistance of state agencies and private consultants. Because the processes are ongoing, it is not possible to be definitive about specific future uses for much of the community at this time. In lieu of a specific future land use scenario for the community, this section describes and explains the various community planning efforts, anticipated schedules for their completion (all within the two year time frame mandated for completion of the Voluntary Clean Up Program), and ways that the VCUP is providing input to the planning efforts to ensure that the public health and safety will be protected. Anticipated general land use patterns are described to the degree possible, with appropriate caveats, and more specific land use standards are outlined for selected parcels targeted for cleanup action.

The town of Rico has embarked on a multi-pronged process to update the master plan for the community. Included in the process are engineering investigations of the water system, physical hazards, waste water treatment, and streets. Simultaneous efforts are addressing the potential of the Dolores River corridor through town and broader issues of land use, appropriate community size and character, and revisions and updates to the land development code of regulations. These studies are being funded by a variety of state grants and local funds supplemented by contributions from a development group that has substantial land holdings in and around the community. As noted elsewhere in this application, the municipal water system obtains water from Silver Creek above the Argentine workings. Gravity flow moves the water to storage tanks on the hillside east of town where it is treated for distribution to all occupied structures throughout the town. The current study, by Harris Water Engineers of Durango, is evaluating system capacity, total supply capability, and general alignment patterns for an appropriate trunk line system. Rico waste water is currently treated in individual septic systems. Recognizing the limitations of this approach in terms of both accommodating expected growth and meeting increasingly stringent water quality standards, the town has contracted with Goff Engineering of Durango to investigate community treatment options. Chris Wilbur, a geotechnical engineer from Durango, has been contracted to develop land use constraint mapping for Rico, emphasizing physical constraints such as avalanche hazard areas, steep slopes, potential subsidence areas, flood hazard areas, wetlands, and prime wildlife use areas. All three of the engineering studies are scheduled to produce at least preliminary results by late summer or early fall 1995.

Rico's master plan update will make use of the results of the engineering studies, together with a survey of community residents, and a new master street plan to establish a vision for how the town will grow and how much growth is desired. RG Plans of Telluride is providing technical assistance on these aspects of the planning effort and will assist the town attorney in translating the new master plan into land use code revisions. The goal for completing the master plan is fall of 1995; code revision adoption is projected for early 1996.

Finally, Rico has been one of a small group of demonstration communities selected by the American Planning Association and the Land Use Resource Center of the University of Colorado at Denver for an open space planning project supported by Great Outdoors Colorado (GOCO) funding. Rico's project, assisted by Community Planning Associates of Telluride, focused on analyzing and planning for the river corridor along the Dolores River. With limited resources, the study identified opportunities and constraints related to protection of the river corridor as a recreational asset of the community. A preliminary preferred recreational river corridor has been identified, although a complex pattern of mainly private ownership along the river is recognized as a constraint to implementation. Among other implementation strategies recommended to facilitate protection of the river corridor, the town is applying for additional GOCO funding to purchase corridor property and/or easements. The proposed local match for the grant would come from donation of river bottom lands to the town by Rico Properties, one of the larger land owners in the corridor.

On the private sector side, Rico Renaissance, the town's largest land owner, has contracted with Jim Burleigh of Telluride to evaluate its land holdings for development potential and to recommend appropriate uses and design standards.

An additional land use consideration that bears long term significance for the community is a proposal by Rico Renaissance for a land exchange with the U.S. Forest Service. The proposal would trade Forest Service lands in and near the town of Rico for scattered private holdings in mountainous areas surrounding the town, consolidating and hopefully rationalizing ownership patterns for both public and private sectors. The exchange process, which was initiated in mid-summer of 1995, will take at least a year to complete if it proceeds successfully (McGerigle 1995).

Rico does have a zoning ordinance in effect regulating town land use. Local officials are reluctant to refer to it as a predictor of long term future use, however, because of the ongoing planning activities and the expectation that important modifications will take place by early 1996. Nevertheless, portions of the code are instructive and worthy of a brief review. The ordinance designates four basic zone districts, an "overlay" district, and a "development area" district. Basic districts include a single family residential district (R-1), a multi-family residential district (R-2) permitting one dwelling unit per 1,250 square feet of lot area, a "commercial historical" district (C-1) intended to preserve the "historical appearance" of the downtown area with pedestrian oriented business uses, and a "commercial" district (C-2) to accommodate auto oriented businesses. The "hazard" overlay district may apply to any of the other districts where flooding, avalanche, or mine related risks have been identified; it requires special review of all use proposals and suggests park or open space uses that do not subject people or property to undue risks. The "Development Area District" is a nebulously defined district, somewhat akin to a "planned unit development" concept in other communities, which may permit a broad range of uses, but requires town review of all uses proposed.

At present, the C-1 area encompasses a two block long strip on both sides of Glasgow Avenue from Soda Street to Campbell Street. The C-2 area adjoins the highway south of town. The R-2 district includes about two and one-half blocks east of the gas station at the south end of town. The remainder of the platted portion of Rico is R-1 and unplatted areas are unzoned.

The ongoing master planning process is expected to change the zoning ordinance and, to some extent, the zoning pattern. Preliminary thinking includes a hillside district for steeper terrain, an open space district, and perhaps a light industrial district, as well as greater definition for the hazard overlay zone district and more specific design standards for the historic commercial core.

Proposals are more specific for future use of lands planned for active cleanup under the VCUP. The two relatively small waste dumps and associated wetland treatment systems for mine drainage at the Silver Swan and Santa Cruz mines are recommended for permanent open space use as part of the river corridor. The Columbia Tailings site is recommended for open space or appropriate recreational uses, such as paved tennis courts. In addition, a visitor welcoming center has been suggested, containing a light, kiosk type structure presenting historical and current community information, a parking lot, and an access point to the river trail. The Atlantic Cable and Van Winkle mine headframes are recommended for preservation as historic features in conjunction with a pedestrian connection to the river corridor trail. The Atlantic Cable site is also being considered as a site for a welcoming center kiosk. Finally, uses of the Argentine mill tailings are less well defined, but town officials have suggested recreational uses such as a soccer field, an outdoor amphitheater, a sledding/ski bunny hill, or some combination of such uses. Technical constraints are being evaluated in the context of the town's suggestions.

Investigations conducted pursuant to the VCUP will provide information to the Rico community on potential hazards related to soil or water contamination from historic mining and milling activities. This information will supplement the community's hazard identification and mapping project, allowing the project's resources to be focused on physical hazards. Implementation of the VCUP will include providing relevant information to the town and working with the town planners and attorney to install appropriate mechanisms to protect public health and safety. In addition, where appropriate, covenants and/or deed restrictions will be attached to key properties to ensure that protective measures are not compromised in the future by inappropriate or uninformed development activities.

APPENDIX C

SILVER SWAN MINE SITE ENGINEERING DATA/CALCULATIONS

- C1 HYDROLOGY
  - C1A RUNON/RUNOFF CALCULATIONS
  - C1B DOLORES RIVER HYDROLOGY
- C2 HYDRAULIC FACILITIES
- C3 WETLANDS DESIGN
- C4 MINE WASTE VOLUME AND ASSAY DATA

C1 HYDROLOGY

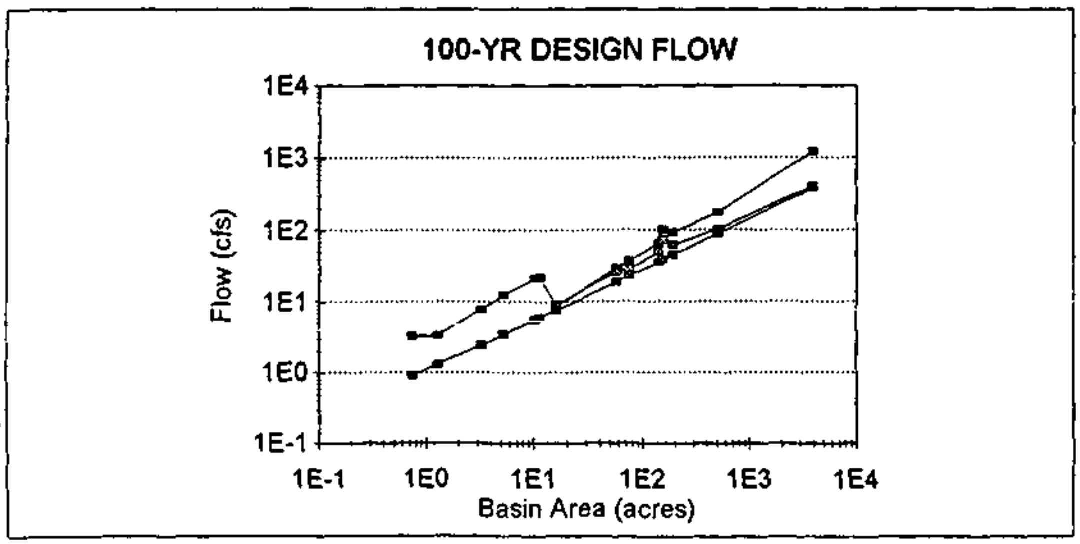
C1A RUNON/RUNOFF CALCULATIONS
C1B DOLORES RIVER HYDROLOGY

C1A RUNON/RUNOFF CALCULATIONS

Summary of Results

Job: 101.9502
Project: Rico
By: ACJ
Re: 100-yr basin runoff

Basin Number	Nickname	Area (acres)	Time of Concentration (min)	Maximum Flow Path: Horizontal Length (ft)	Maximum Flow Path: Vertical Drop (ft)	Maximum Flow Path: Average Slope (ft/ft)	Maximum Flow Path: Average Water Velocity* (fps)	Q(cfs): Rational Method	Q(cfs): TR-55	Q(cfs): Regional Regression	Q/A (cfs/ac)
Santa Cruz	Pile Runoff	0.75	4.4	160	33	21%	0.6	3.2	-	0.9	4.27
Silver Swan	Pile Runoff	1.3	18.6	315	9	3%	0.3	3.3	-	1.3	2.54
Columbia Tailings	Pile Runoff	3.3	22.6	800	12	2%	0.6	7.7	-	2.4	2.33
Argentine Tailings	Pile Runoff - Area A	5.3	23	1050	20	2%	0.8	12.3	-	3.4	2.32
	Pile Runoff - Area A,B	10.3	27.5	1650	85	5%	1.0	21.3	-	5.5	2.07
	Pile Runoff - Area A,B,C	11.5	31.4	2150	115	5%	1.1	21.8	-	5.9	1.90
A7		16	16.3	1250	350	28%	1.3	8.7	9.0	7.5	0.54
A5		58	19.8	3950	1500	38%	3.6	29	26	19	0.45
A8		76	22.4	5750	2000	35%	4.5	37	28	23	0.37
A9		142	24.1	6350	1790	28%	4.6	66	50	35	0.35
A3		154	11.3	2500	1639	66%	4.4	98	72	38	0.47
A10	Spear Slide	192	24.0	8250	3400	41%	6.2	90	61	44	0.32
A6	Sulphur Creek	521	43.8	11800	3371	29%	4.7	174	101	89	0.19
Silver Creek Basin	(at Argentine Tailings)	4000	58.8	21800	3481	16%	6.3	1205	408	378	0.09



* Calculated using slope distance. Overland and shallow concentrated flow times included.

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Attachment C1A-1
Rainfall Data

Region of applicability[a]	Equation	Corr. coeff.	No. of stations	Mean of computed stn. values (inches)	Standard error of estimate (inches)
South Platte, Republican, Arkansas, and Cimarron River Basins (1)	$Y_2 = 0.218 + 0.709[(X_1)(X_1/X_2)]$	0.94	75	1.01	0.074
	$Y_{100} = 1.897 + 0.439[(X_3)(X_3/X_4)] - 0.008Z$	.84	75	2.68	.317
San Juan, Upper Rio Grande, Upper Colorado, and Gunnison River Basins and Green River Basin below confluence with the Yampa River (2)	$Y_2 = -0.011 + 0.942[(X_1)(X_1/X_2)]$	.95	86	0.72	.085
	$Y_{100} = 0.494 + 0.755[(X_3)(X_3/X_4)]$	.90	85	1.96	.290
Yampa and Green River Basins above confluence of Green and Yampa Rivers (3)	$Y_2 = 0.019 + 0.711[(X_1)(X_1/X_2)] + 0.001Z$	.82	98	0.40	.031
	$Y_{100} = 0.338 + 0.670[(X_3)(X_3/X_4)] + 0.001Z$	.80	79	1.04	.141
North Platte (4)	$Y_2 = 0.028 + 0.890[(X_1)(X_1/X_2)]$	.93	90	0.60	.062
	$Y_{100} = 0.671 + 0.757[(X_3)(X_3/X_4)] - 0.003Z$	.91	88	1.71	.236

[a] Numbers in parentheses refer to geographic regions shown in figure 19. See text for more complete description.

List of variables

Y_2 = 2-yr 1-hr estimated value
Y_{100} = 100-yr 1-hr estimated value
X_1 = 2-yr 6-hr value from precipitation-frequency maps
X_2 = 2-yr 24-hr value from precipitation-frequency maps
X_3 = 100-yr 6-hr value from precipitation-frequency maps
X_4 = 100-yr 24-hr value from precipitation-frequency maps
Z = point elevation in hundreds of feet

Figure 15. *Ratio of 2-yr 24-hr value for all data to 2-yr 24-hr value for rainfall only vs. latitude.*

15 percent, with some individual differences as large as 40 to 50 percent. About half the stations have differences greater than 10 percent. These differences indicate that frequency values computed from an annual series of rainfall amounts only would be different from those composed of all-precipitation values, and two separate sets of precipitation-frequency maps were needed.

Snowfall observations are made at only about 15 percent of the precipitation stations used in this study. For this reason, a rainfall-frequency study could not be made by direct methods. Since most snowfall occurs during the colder half of the year, a series containing only values for the May to October season was compared with the series that was based on rainfall only. The two series were in good agreement, except for a slight bias toward higher values for the May to October season. This bias results from some large amounts in late October and early May occurring as snow and thus excluded from the rainfall-only series. The average difference is only about 4 percent, with no consistent preference toward higher elevations or particular geographic regions.

Two sets of maps were prepared for Colorado. The first set consists of annual maps based on precipitation data from all months of the year without regard to the type of precipitation: rain; rain and snow mixed, all snow, hail; etc. The second series takes precipitation values from the months May to October. No attempt was made in this second series to differentiate between types of precipitation occurring within these months, but the investigations mentioned in the preceding paragraph indicate that these maps will approximate the values that would be obtained by using a data series made up of precipitation events that are exclusively rain. Since data for only part of the year were used, these maps have been labeled with the appropriate probabilities rather than with a return period in years (figs. 32–43).

Duration (min)	5	10	15	30
Ratio to 1-hr	0.29	0.45	0.57	0.79

(Adopted from *U.S. Weather Bureau Technical Paper No. 40*, 1961.)

Procedures for Estimating Values for Durations Other Than 6 and 24 Hrs

The isopluvial maps in this Atlas are for 6- and 24-hr durations. For many hydrologic purposes, values for other durations are necessary. Such values can be estimated using the 6- and 24-hr maps and the empirical methods outlined in the following sections. The procedures detailed below for obtaining 1-, 2-, and 3-hr estimates were developed specifically for this Atlas. The procedures for obtaining estimates for less than 1-hr duration and for 12-hr duration were adopted from *Weather Bureau Technical Paper* No. 40 (U.S. Weather Bureau 1961) only after investigation demonstrated their applicability to data from the area covered by this Atlas.

Procedures for estimating 1-hr (60-min) precipitation-frequency values. Multiple-regression screening techniques were used to develop equations for estimating 1-hr duration values. Factors considered in the screening process were restricted to those that could be determined easily from the maps of this Atlas or from generally available topographic maps.

The 11 western states were separated into several geographic regions. The regions were chosen on the basis of meteorological and climatological homogeneity and are generally combinations of river basins separated by prominent divides. Four of these geographic regions are partially within Colorado. For convenience and use as an overlay on the precipitation-frequency maps, these regions are outlined on figure 19. The first Colorado region is part of the region that lies to the east of the Continental Divide and the crest of the Sangre de Cristo and Sacramento Mountains and is south of the divide separating the drainage basins of the North and South Platte Rivers. It consists of that portion of Colorado drained by the South Platte, Republican, Arkansas, and Cimarron Rivers (Region 1, fig. 19). The second region consists of the area drained by the San Juan, Upper Rio Grande, Upper Colorado, and Gunnison Rivers and by the Green River below its confluence with the Yampa River (Region 2, fig. 19). This is part of a larger region that extends from southwestern Colorado, westward to the Wasatch Mountains of Utah, and southward through Arizona and the western half of New Mexico. The third region is the mountainous portion of the area between the Continental Divide and the crest of the Cascade Range. The portion that lies within Colorado is the northwestern portion of the State that is drained by the Yampa River and the Green River above its confluence with the Yampa (Region 3, fig. 19). A small portion of Colorado drained by the North Platte is Region 4, figure 19. The larger region of which this is a part includes that portion of Wyoming and Montana east of the Continental Divide. Equations to provide estimates for the 1-hr duration for 2- and 100-yr return periods are shown in table 11. Also listed are the statistical parameters associated with each equation. In these equations, the variable $[(X_1)(X_1/X_2)]$ or

[$(X_1)(X_6/X_1)$] can be regarded as the 6-hr value times the slope of the line connecting the 6- and 24-hr values for the appropriate return period.

As with any separation into regions, the boundary can only be regarded as the sharpest portion of a zone of transition between regions. These equations have been tested for boundary discontinuities by computing values using equations from both sides of the boundary. Differences were found to be mostly under 15 percent. However, it is suggested that when computing estimates along or within a few miles of a regional boundary computations be made using equations applicable to each region and that the average of such computations be adopted.

Estimates of 1-hr precipitation-frequency values for return periods between 2 and 100 yrs. The 1-hr values for the 2- and 100-yr return periods can be plotted on the nomogram of figure 6 to obtain values for return periods greater than 2 yrs or less than 100 yrs. Draw a straight line connecting the 2- and 100-yr values and read the desired return-period value from the nomogram.

Estimates for 2- and 3-hr (120- and 180-min) precipitation-frequency values. To obtain estimates of precipitation-frequency values for 2 or 3 hrs, plot the 1- and 6-hr values from the Atlas on the appropriate nomogram of figure 16. Draw a straight line connecting the 1- and 6-hr values, and read the 2- and 3-hr values from the nomogram. This nomogram is independent of return period. It was developed using data from the same regions used to develop the 1-hr equations.

The mathematical solution (from the data used to develop figure 16 gives the following equations for estimating the 2- and 3-hr values:

For Region 1,	2-hr = 0.342 (6-hr) + 0.658 (1-hr)	(3)
figure 19	3-hr = 0.597 (6-hr) + 0.403 (1-hr)	(4)
For Region 2,	2-hr = 0.341 (6-hr) + 0.659 (1-hr)	(5)
figure 19	3-hr = 0.569 (6-hr) + 0.431 (1-hr)	(6)
For Regions 3	2-hr = 0.250 (6-hr) + 0.750 (1-hr)	(7)
and 4, figure 19	3-hr = 0.467 (6-hr) + 0.533 (1-hr)	(8)

Estimates for 12-hr (720-min) precipitation-frequency values. To obtain estimates for the 12-hr duration, plot values from the 6- and 24-hr maps on figure 17. Read the 12-hr estimates at the intersection of the line connecting these points with the 12-hr duration line of the nomogram.

Estimates for less than 1 hr. To obtain estimates for durations of less than 1 hr, apply the values in table 12 to the 1-hr value for the return period of interest.

Illustration of Use of Precipitation-Frequency Maps, Diagrams, and Equations

To illustrate the use of these maps, values were read from figures 20 to 31 for the point at 39°00′ N. and 106°00′ W. These values are shown in boldface type in table 13. The values read from the maps should be plotted on the return-period diagram of figure 6 because (1) not all points are as easy to locate on a series of maps as are latitude-longitude intersections, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. This has been done for the 24-hr values in table 13 (fig. 18a) and a line of best fit has been drawn subjectively. On this nomogram, the line fits the data rather well. Had any points deviated noticeably from the line, the value would have been reread from the line and the new value substituted in table 13 and adopted in preference to the original readings.

The 2- and 100-yr 1-hr values for the point were computed from the equations applicable to Region 1, figure 19 (table 11), since the point is east of the Continental Divide. The 2-yr 1-hr value is estimated at 0.71 in. (2-yr 6- and 24-hr values from table 13); the estimated 100-yr 1-hr value is 1.86 in. (100-yr 6- and 24-hr values from table 13 and elevation of 9,500 ft). By plotting these 1-hr values on figure 6 and connecting them with a straight line, one can obtain estimates for return periods of 5, 10, 25, and 50 yrs.

The 2- and 3-hr values can be estimated by using the nomogram of figure 16 or equations (3) and (4). The 1- and 6-hr values for the desired return period are obtained as above. Plot those points on the nomogram of figure 16 and connect them with a straight line. Read the estimates for 2 or 3 hrs at the intersections of the connecting line and the 2- and 3-hr vertical lines. An example is shown in figure 18b for the 2-yr return period. The 2-yr 2-hr (0.83 in.) and 2-yr 3-hr (0.91 in.) values are in italics on table 13.

	1-hr	2-hr	3-hr	6-hr	24-hr
2-yr	*0.71*	*0.83*	*0.91*	**1.05**	**1.58**
5-yr				**1.38**	**1.99**
10-yr				**1.59**	**2.27**
25-yr				**1.80**	**2.65**
50-yr				**2.19**	**2.95**
100-yr	*1.86*			**2.39**	**3.35**

Table 13. *Precipitation data for depth-frequency atlas computation point 106°00′ W., 39°00′ N.*

Figure 18. *Precipi*
4. Sou

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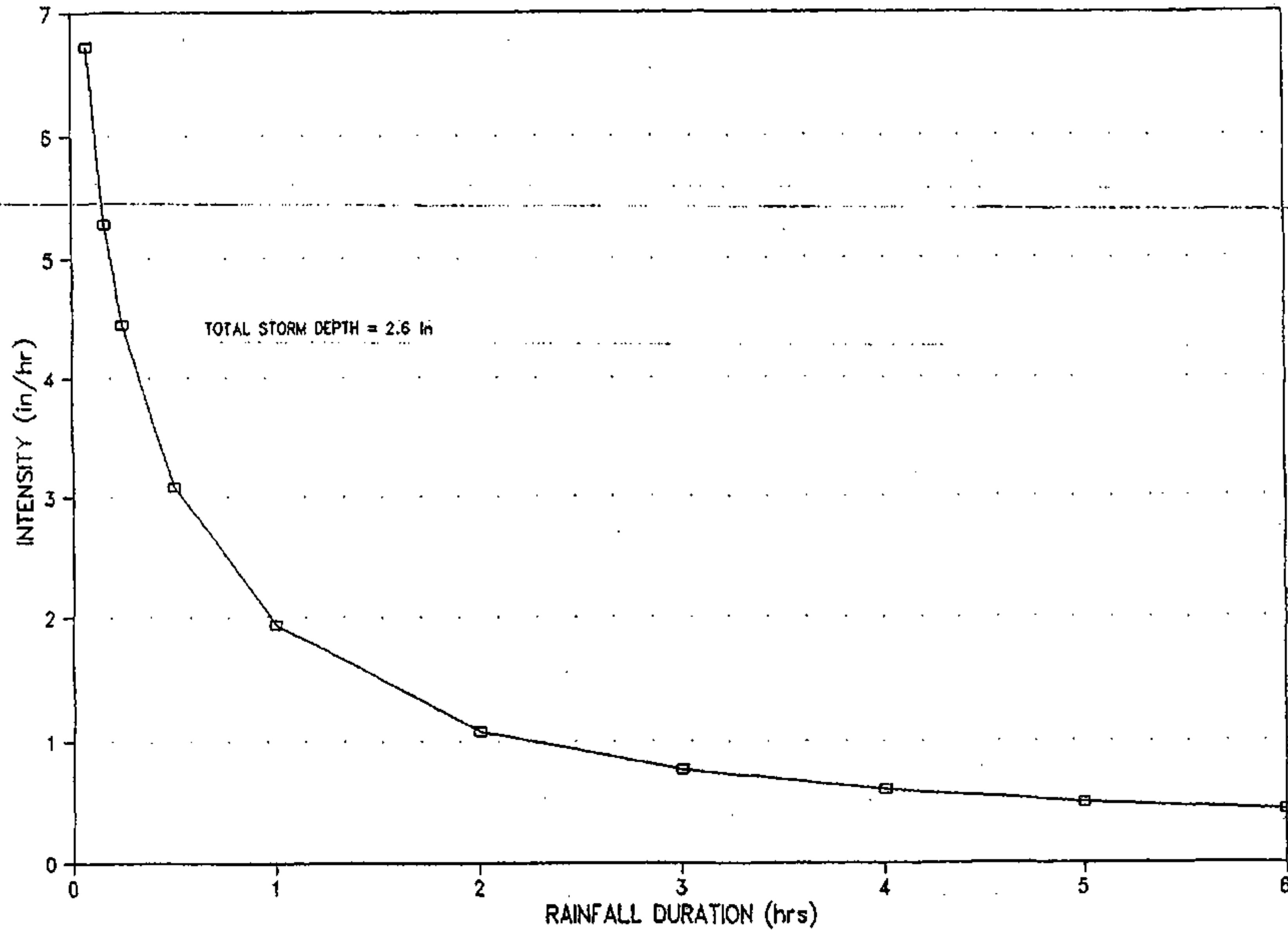
100 YR 6 HR DESIGN STORM AND DISCHARGE FOR RICO C
07/27/95

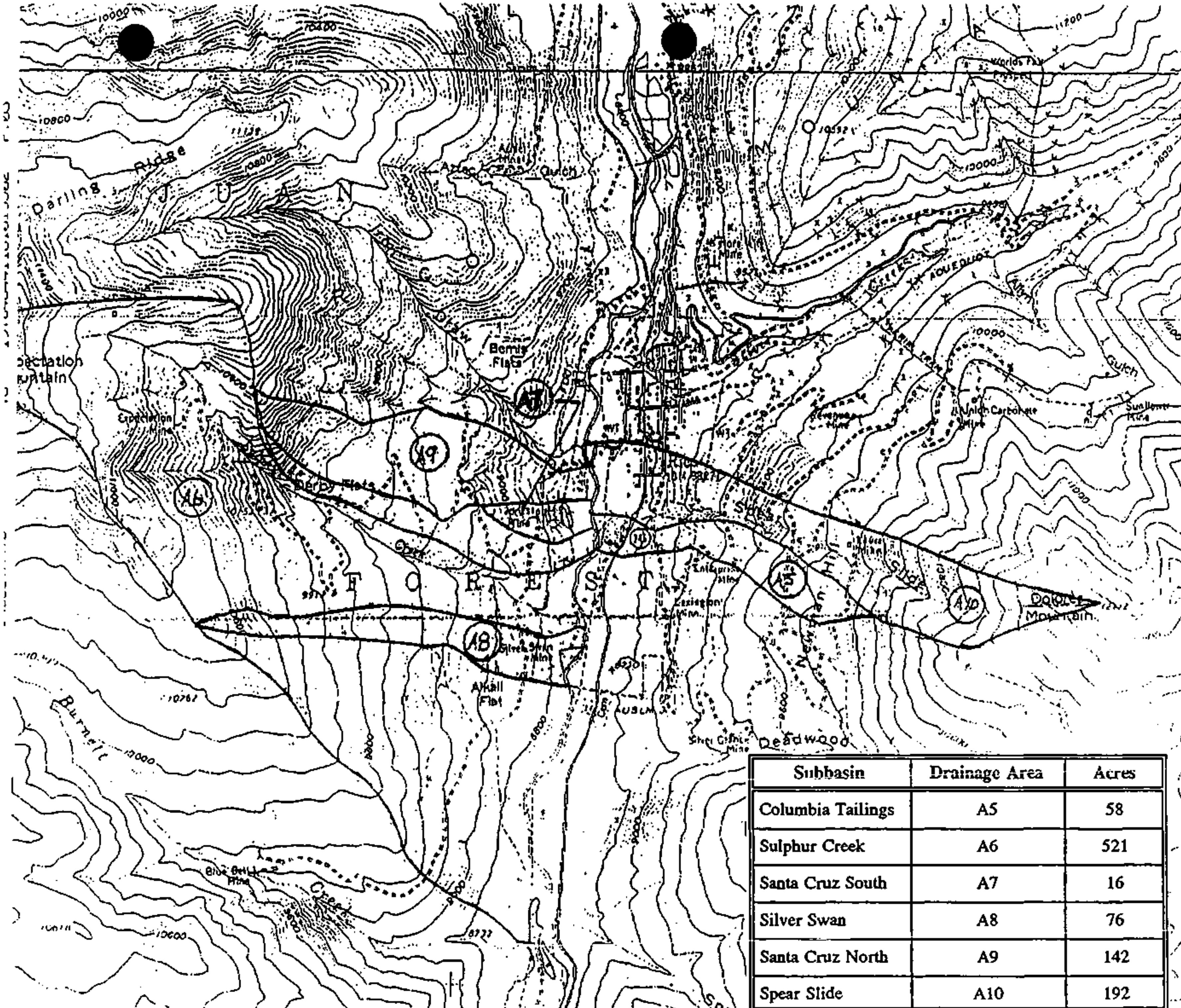
REF: NOAA ATLAS 2, VOL III
DESIGN STORM
100 YR - 6HR

PERIOD (hrs)	TOTAL DEPTH (IN)	INC DEPTH (IN)	INTENSIT (in/hr)	SORTED INC DEPTH (IN)	ARRANG INC DEPTH (IN)
0.083333	0.56	0.56	6.72	0.56	0.08
0.166667	0.88	0.32	5.28	0.43	0.1
0.25	1.11	0.23	4.44	0.41	0.15
0.5	1.54	0.43	3.08	0.32	0.22
1	1.95	0.41	1.95	0.23	0.32
2	2.17	0.22	1.085	0.22	0.43
3	2.32	0.15	0.773333	0.15	0.56
4	2.4	0.08	0.8	0.1	0.41
5	2.5	0.1	0.5	0.1	0.23
6	2.6	0.1	0.433333	0.08	0.1
				TOTAL =	2.6

100 YR – 6HR DESIGN STORM
RICO COLORADO



Attachment C1A-2
Basin Delineations



SCALE 1" = 2000'

Subbasin	Drainage Area	Acres
Columbia Tailings	A5	58
Sulphur Creek	A6	521
Santa Cruz South	A7	16
Silver Swan	A8	76
Santa Cruz North	A9	142
Spear Slide	A10	192

Attachment C1A-3
Rational Method Methodology

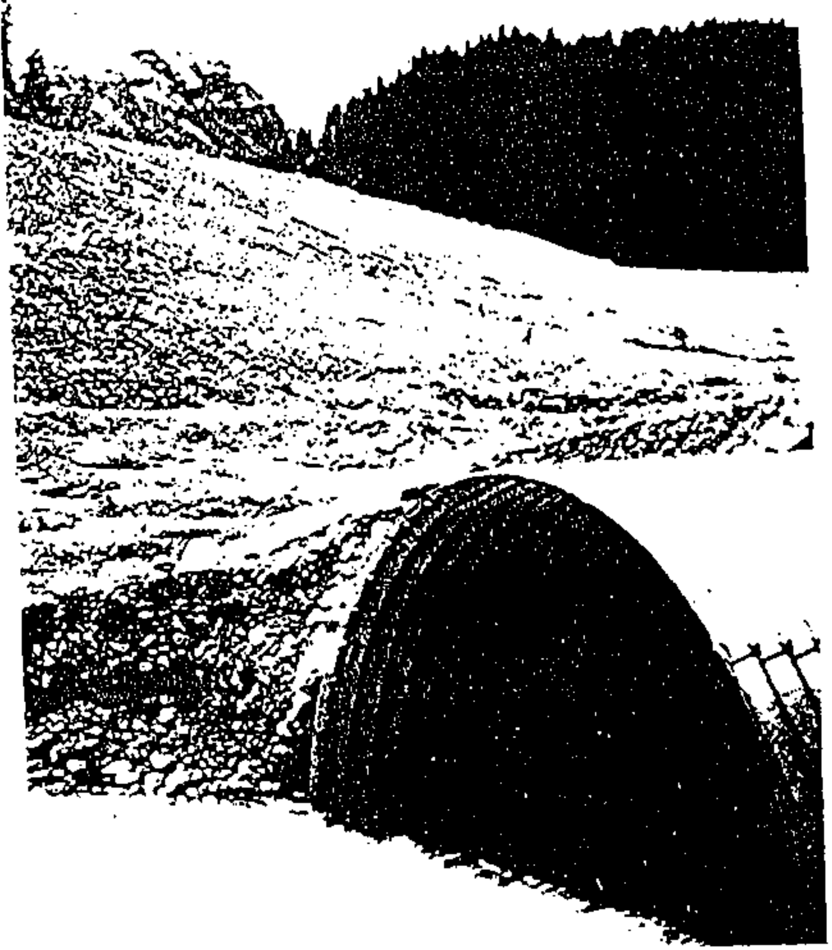


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Figure 3.1 Effective handling of drainage requires comprehensive hydraulic design.

CHAPTER 3 Hydraulics

INTRODUCTION

Many millions of dollars are spent annually on culverts, storm drains and subdrains, all vital to the protection of streets, highways and railroads. If inadequate, they can jeopardize the roadway and bring excessive property damage and loss of life. Overdesign means extravagance. Good engineering can find an economic solution.

Because topography, soil and climate combine in infinite variety, drainage sites should be designed individually from reasonably adequate data for each particular site. In addition, the designer is advised to consult with those of long experience in maintaining drainage structures in the area. One state highway engineer comments:

> "With the exception of the riding qualities of the traveled way, no other single item requires as much attention on the part of the maintenance man as highway culverts. Many of the problems of culvert maintenance stem from the fact that designers in all too many instances consider that culverts will be required to transport only clear water. This is a condition hardly ever realized in practice, and in many instances storm waters may be carrying as much as 50 percent detrital material which, due to a rapid change in grade line at the culvert entrance, causes complete blockage of the culvert, with resulting overflow across the highway and in some cases, especially where high fills are involved, the intense static pressure results in loss of the embankment."

HYDROLOGY

The hydrological cycle as presented in many hydrology textbooks is defined as a group of numerous inter-related phenomena representing the different paths through which water in nature circulates and is transformed. A simplistic representation of this cycle is schematicized below. (Fig. 3.2)

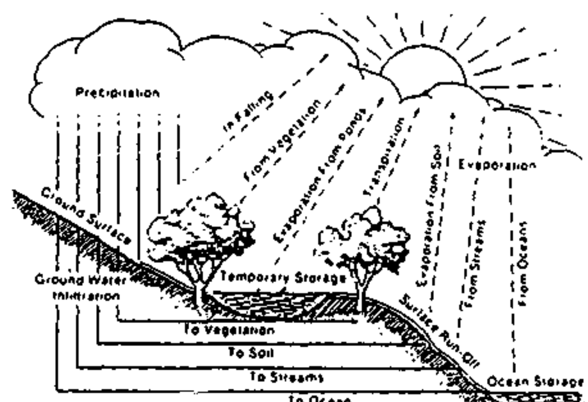


Figure 3.2 Hydrologic cycle—where water comes from and where it goes. From M G Spangler's *Soil Engineering*.[1]

*Superior numbers indicate references at the end of this chapter

Due to our complex urban environment such ... ger valid. Modification of natural drainage paths, damming of waterways, impoundment of water, re-use of storm water and implementation of new storm water management processes results in highly intricate hydrologic processes.

The objective of this section will be to introduce the designer to different methods of estimating the hydrologic process from the precipitation state to runoff.

ESTIMATION OF RAINFALL

The amount of rainfall and distribution of rainfall over time is usually the required input for most runoff calculations. This input may be in the form of actual rainfall events, representative design storms, the widely used intensity duration frequency curves, or statistical analysis of rainfall records.

Rainfall Intensity-Duration Frequency Curves (Fig. 3.3)

Rainfall intensity-duration frequency (IDF) curves are derived from the statistical analysis of rainfall records compiled over a number of years. Each curve represents the intensity-time relationship for a certain return frequency, from a series of storms. These curves are then said to represent storms of a specific return frequency.

The intensity, or the rate of rainfall is usually expressed in depth per unit time with the highest intensities occurring over short time intervals and progressively decreasing as the time intervals increase. The greater intensity of the storm the lesser their recurrence frequency, thus the highest intensity for a specific duration for n years of records, is called the n year storm, with a frequency of once in n years.

Using Tabulated data

(hrs)	in	i(in/hr)	Time (min)
.083	.54	6.75	5
.167	.88	5.27	10
.25	1.11	4.44	15
.5	1.54	3.08	25
1.0	1.95	1.95	60

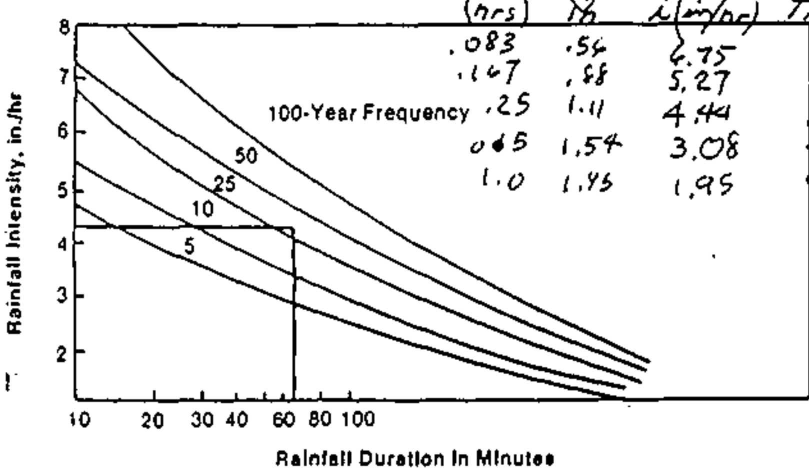


Figure 3.3 Example curve showing rainfall intensities for various storm frequencies vs. rainfall duration.

The curves may be in the graphical form as the example shown in Figure 3.3, or may be represented by individual equations that express the time intensity relationship for specific frequencies, in the form:

$$i = \frac{a}{(t + c)^b}$$

where:

i = intensity (in./hr.)
t = time in minutes
a,b,c = constants developed for each IDF curve

The fitting of rainfall data to the equation may be obtained by either graphical or least square methods.[2]

It should be noted that the I.D.F. curves *do not* represent a rainfall pattern, but are the distribution of the highest intensities over time durations for a storm of n frequency.

The rainfall-intensity-duration curves are readily available from governmental agencies, local municipalities and towns, and as such are widely used in the designing of drainage facilities and flood flow analysis.

Rainfall Hyetographs

Rainfall hyetographs are a graphical representation of the intensity distribution of a rainfall event over time. (Fig. 3.4)

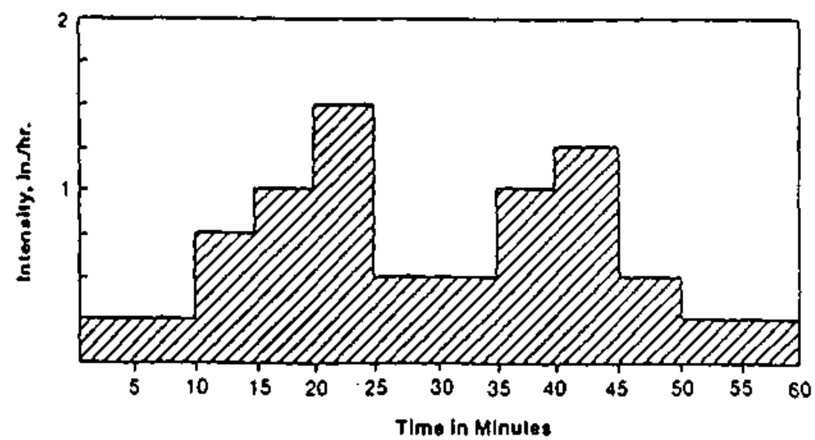


Figure 3.4 Example synthetic rainfall hyetograph.

Rainfall hyetographs are available from weather stations which have recording gauges.

Synthetic Rainfall Hyetographs (Fig. 3.5)

Hyetographs are often not available for all locations or a standard hyetograph may be required for designing of the drainage system. In such cases a synthetic hyetograph may be developed to be representative of a certain design storm. The synthetic hyetograph may be derived from the I.D.F. curve of a specified return period using the Chicago method.

The I.D.F. curve is required in the form

$$i = \frac{a}{(t + c)^b}$$

The rising and receding legs of the hyetographs are described by the following equations:

b) After the peak

$$i_a = \frac{a\left[(1-b)\dfrac{t_a}{(1-r)} + c\right]}{\left(\dfrac{t_a}{(1-r)} + c\right)^{1+b}}$$

a) Before the peak

$$i_b = \frac{a\left[(1-b)\dfrac{t_b}{(r)} + c\right]}{\left(\dfrac{t_b}{(r)} + c\right)^{1+b}}$$

where: t_a = time after peak
t_b = time before peak
r = ratio of time before the peak occurs to the total duration time (the value of r is derived from analysis of actual rainfall events)

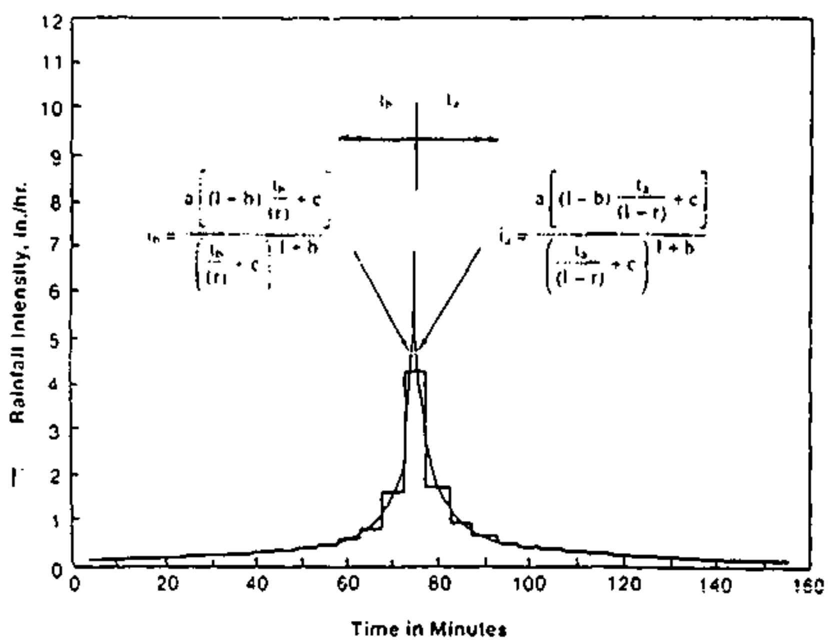


Figure 3.5 Example synthetic rainfall hyetograph.

RAINFALL-RUNOFF RELATIONSHIPS

The volume and peak flows of the rainfall runoff is one of the key factors in the design of stormwater drainage facilities.

From Figure 3.6 it can be deduced that the net storm rain (that portion of the total precipitation which will appear as direct surface runoff) can be obtained from consideration of the phenomena of retention, infiltration and overland flow. Essentially, in terms of watershed yield (surface runoff), one may write a simple continuity equation:

Inflow = Outflow + Change in Storage.

Precipitation = Depressional Storage + Evaporation + Infiltration + Interception + Surface Runoff.

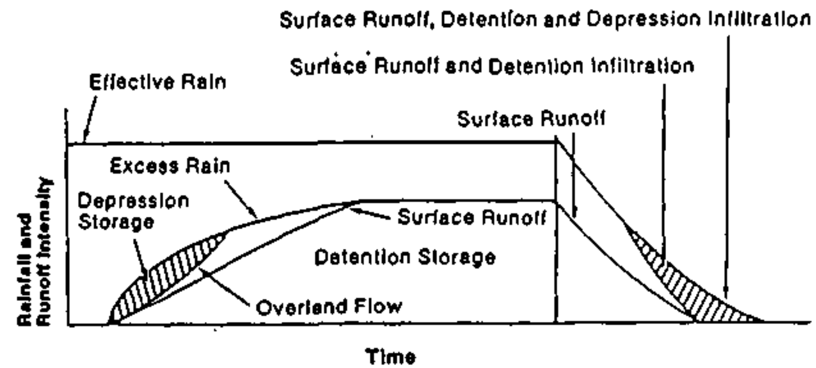


Figure 3.6 Hydrographs showing the rates of disposition of a hypothetical, uniform, effective rainfall.

Evaporation

Evaporation is the process by which water changes in state from liquid to gas. In the hydrological practice evaporation is defined as the net rate of vapor transfer. It is estimated that approximately 75 per cent of the total annual precipitation is returned to the earth's atmosphere. During a single rainfall event evaporation is negligible, but should be considered when long term continuous rainfall-runoff is being simulated.

Interception

Interception is defined as that portion of the precipitation falling to the earth's surface which may be stored on above ground objects until it is returned to the atmosphere by evaporation.

Interception as a percentage of total rainfall may vary from 10 to 25 per cent in areas with some vegetal cover.

Depression Storage

Precipitation which reaches the ground may become trapped in small depressions on the surface, from which the only escape is infiltration or evaporation. The amount of depression storage available is a function of the land use. The following empirical equation has been developed to represent this process.

$V = Sd\,(1 - e^{-kPe})$
V = volume of storage at any particular time
Sd = maximum storage capacity of depression
Pe = rainfall excess = gross rainfall minus evaporation, interception and infiltration
k = 1/sd constant

Table 3.1 Typical Depression and Detention for Various Land Covers[5]

Land Cover	Depression & Detention, In.	Recommended, In.
Impervious:		
Large Paved Areas	0.05 – 0.15	0.1
Pervious:		
Lawn Grass	0.2 – 0.5	0.3
Wooded Area and Open Fields	0.2 – 0.6	0.4

Infiltration

Infiltration is the most important abstraction in the surface runoff phenomena. It is defined as the flow of water into the ground through the earth's surface. The degree of infiltration is affected by the type and extent of the vegetal cover, surface conditions, temperature, rainfall intensity, soil properties and water quality. Field tests have shown that bare-soil infiltration can be increased by 3 to 7.5 times with good permanent forest or grass cover, but little or no increase with poor row crops. Empirical relationships describing infiltration have been developed with one of the simplest being the Φ Index Method. This method assumes that infiltration occurs at some constant rate over the duration of the rainfall event. This method tends to underestimate infiltration early in the storm and overestimates it late in the storm. Thus the method should be applied to wet soils, or high intensity storms where the rate of infiltration is assumed to have reached a constant rate early in the storm. (Fig. 3.7)

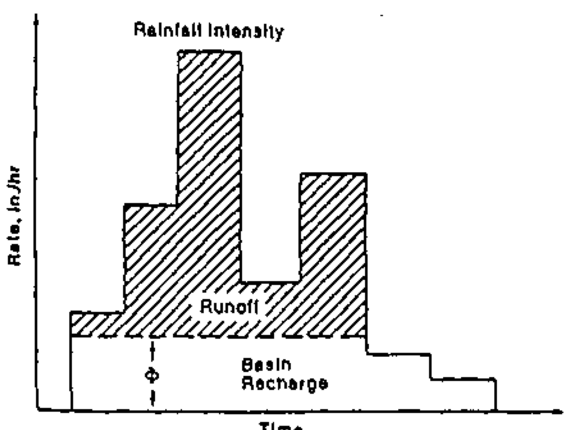


Figure 3.7 Schematic diagram illustrating the derivation and meaning of the Φ index.

Horton developed a mathematical equation for defining the rate curve of infiltration capacity:

$$f = f_c + (f_0 - f_c)\,e^{-kt}$$

where:
f = rate of infiltration at period of time
f_c = minimum rate of infiltration
f_0 = initial rate of infiltration
k = rate of decrease in f per unit of time
t = time

A typical residential infiltration curve has the equation

$$f = .52 + (3 - .52)e^{-.00115t}$$

note k = .0015 per second in this case, fc and fo in in./hr
Typical infiltration curves are shown in Figure 3.8.

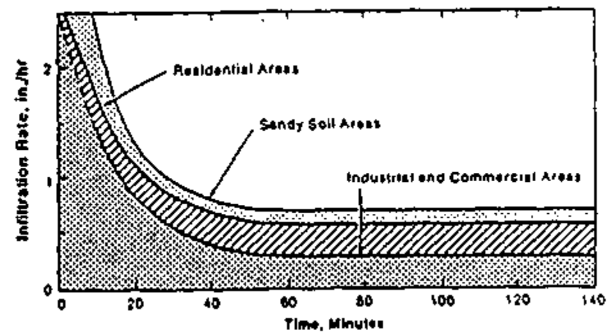


Figure 3.8 Pervious surface infiltration-capacity curves.[5]

Estimation of Runoff

A number of methods to estimate the amount of runoff are available today. They range from the widely used rational formula developed in the late 1800's to the more recently developed computer models that are being upgraded continuously. The method selected should be based on the size of drainage area, the data available, and the degree of sophistication warranted for the design. The criteria for selecting the most suitable method is described in the following section.

RATIONAL METHOD

The rational method for estimating peak flows is the method most widely used by design engineers. It is based on a simple intensity-runoff relationship:

$$Q = CIA \quad (1)$$

where:

English	Metric
Q = runoff, ft^3/sec	Q = CIA x 2.78 liter/sec (l/s)
C = runoff coefficient	C = runoff coefficient
I = intensity, in./hr	I = intensity, mm/hr

When using the rational method, the following assumptions are considered:

1) the rainfall intensity is uniform over the entire watershed during the entire storm duration.
2) the maximum runoff rate occurs when the rainfall lasts as long or longer than the time of concentration.
3) the time of concentration is the time required for the runoff from the most remote part of the watershed to reach the point under design.

Runoff Coefficient (C)

Since the only manipulative factor in the rational formula is the runoff coefficient (C) judgement should be used in selecting this value, as it must incorporate most of the hydrological abstractions, soil types, antecedent conditions, etc. Values of typical C coefficients are listed in Table 3.2.

Table 3.2 Values of Relative Imperviousness

Type of Surface	Factor C
For all watertight roof surfaces	0.75 to 0.95
For asphalt runway pavements	0.80 to 0.95
For concrete runway pavements	0.70 to 0.90
For gravel or macadam pavements	0.35 to 0.70
*For impervious soils (heavy)	0.40 to 0.65
*For impervious soils, with turf	0.30 to 0.55
*For slightly pervious soils	0.15 to 0.40
*For slightly pervious soils, with turf	0.10 to 0.30
*For moderately pervious soils	0.05 to 0.20
*For moderately pervious soils, with turf	0.00 to 0.10

*For slopes from 1% to 2%

Modifications to the rational method have been proposed in order that the C coefficient may account for antecedent precipitation conditions. Recommended Antecedent Precipitation Factors are listed below. The rational formula now includes a new variable: $Q = C\,C_a\,I\,A$

Recommended Antecedent Precipitation Factors for the Rational Formula

Recurrence Interval (Years)	C_a
2 to 10	1.0
25	1.1
50	1.2
100	1.25

NOTE: The product of $C \times C_a$ should not exceed 1

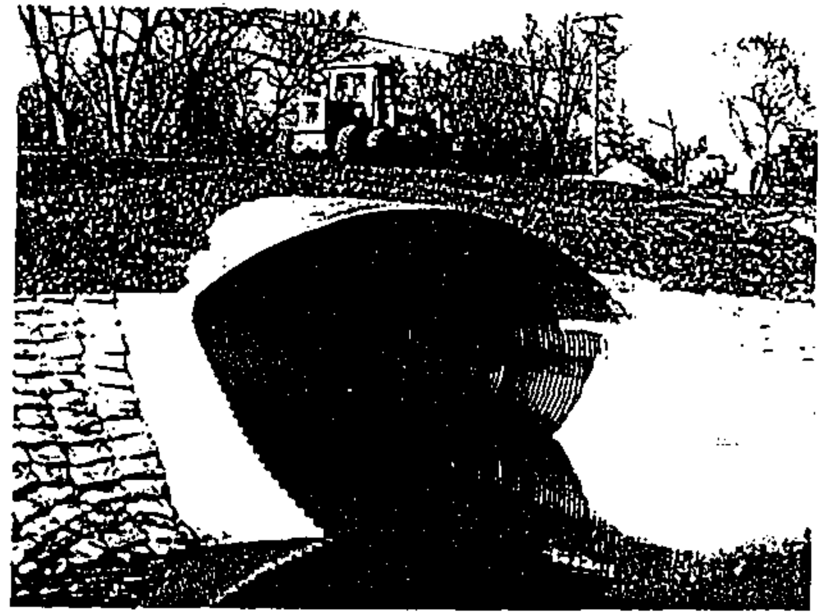


Figure 3.9

Time of Concentration for Small Watersheds

According to the theory underlying the Rational Method, maximum discharge at any point in a drainage system occurs when:

1) The entire area tributary to that point is contributing to the flow.
2) The rainfall intensity producing such flow is based upon the rate of rainfall which can be expected to fall in the time required for water to flow from the most remote point of the area to the point being investigated. The "most remote point" is the point from which the time of flow is greatest. It may not be at the greatest linear distance from the point under investigation.

A minimum time of 5 minutes is recommended by the Federal Highway Administration. A Time of Concentration Nomograph (Fig. 3.10) may be used to assist with the hydrologic analysis.

The drainage area can be measured on a topographic map or determined in the field by estimation, pacing, aerial photos, or a survey comparable in accuracy to a stadia-compass traverse.

Example

Find the discharge for a 10-year frequency rainfall at the outlet of a grassed roadside channel 400 ft from the crest of a hill with the contributing area 238 ft wide, consisting of 12 ft of concrete pavement, 26 ft of gravel shoulder, channel, and 200 ft backslope of grassed pasture—giving a weighted C = 0.35. The channel grade is 0.5 per cent; and the outer edge of the contributing area is 4 ft above the channel. Location is near Washington, D.C.

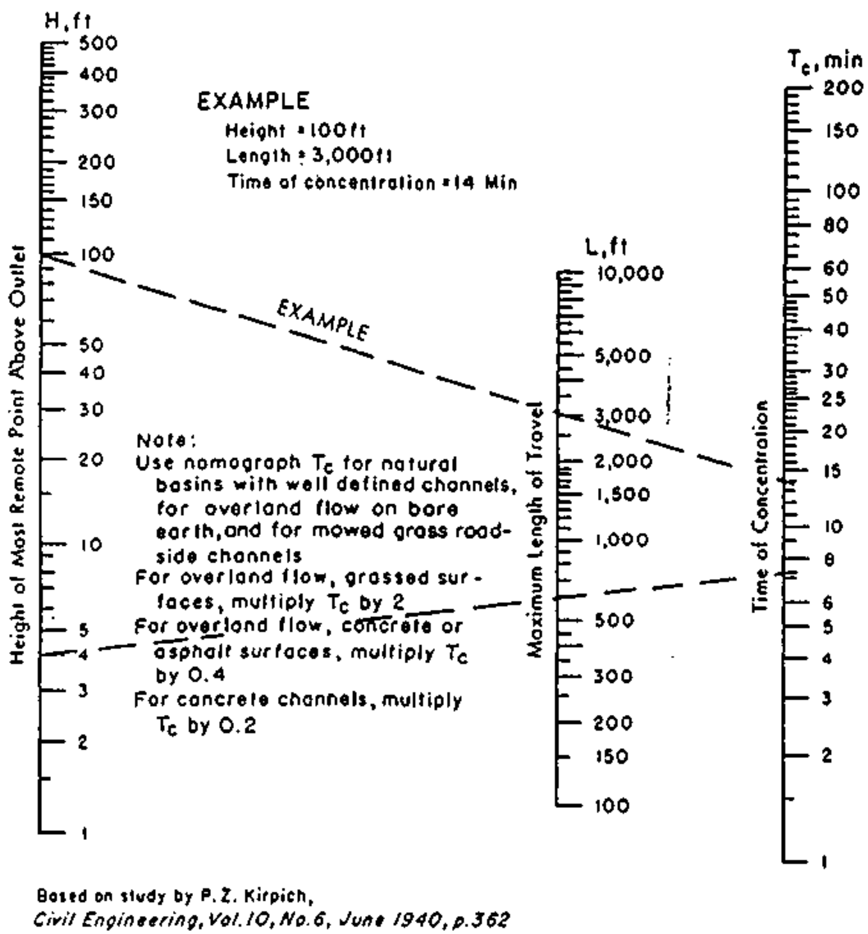


Figure 3.10 Time of concentration of rainfall on small drainage basins.

The distance from the channel to the ridge of the area is 210 ft and that of the channel is 400 ft making $L = 610$ ft. The height of the most remote point above the outlet = 4 ft + (0.005 × 400) = 6 ft. From (Fig. 3.10), the time of concentration, $Tc = 6.5$ min.

The rainfall intensity for a 6.5 minute duration and 10-year return period is 6.9 in./hr.

The drainage area = 238 × 400 = 95,200 ft² or

$$\frac{95{,}200}{43{,}560} = 2.2 \text{ acres}$$

Then Q [illegible] 35 × 6.9 × 2.2 = 5.3 ft³/sec.

TIME OF CONCENTRATION FOR LARGE WATERSHEDS

In large watersheds Tc should be obtained from stream flow records or field inspection of the stream channel and watershed characteristics. When such data is unavailable, the following empirical equation for concentration may be used for estimating the time of concentration:

Kirpich (1940)

$$Tc = 0.00013 \frac{L^{0.77}}{S^{0.385}} \text{ (Fig. 3.11)}$$

in which Tc = time of concentration, hrs
L = maximum length of travel of water, ft
S = slope, equal to H/L where H is the difference in elevation between the most remote point on the basin and the outlet, ft/ft

Note: Use Kirpich equation for natural basins with well defined channels for overland flow on bare earth, and mowed grass roadside channels. For overland flow, grassed surfaces, multiply Tc by 2. For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4. For concrete channels, multiply Tc by 0.2.

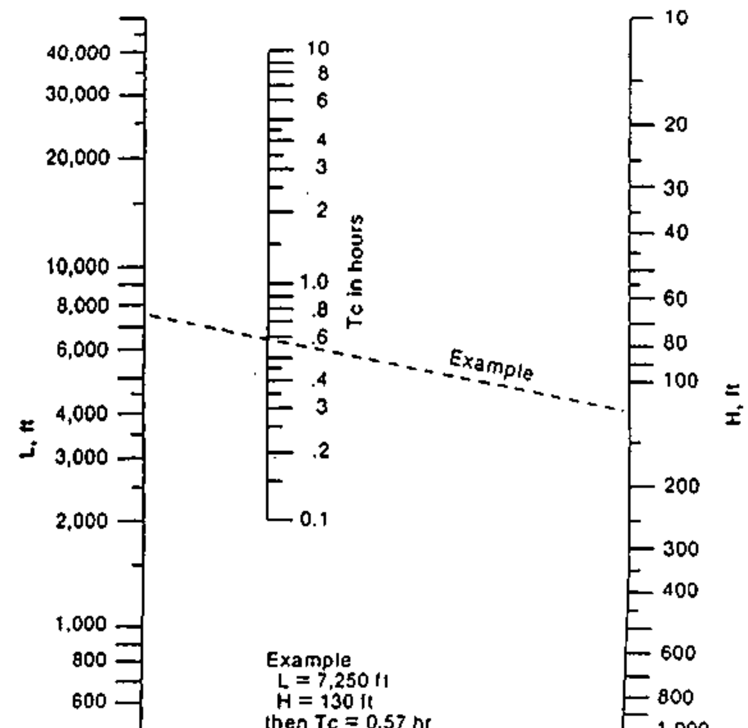


Figure 3.11 Tc nomograph for large watersheds.

When calculating travel times for overland flow in watersheds with a variety of land covers, the Uplands Method may be used. The individual times are calculated, with their summation giving the total travel time. (Fig. 3.12). In large watersheds greater than 2000 acres, the stream flow velocities under the flood flow conditions should be used to estimate the Tc.

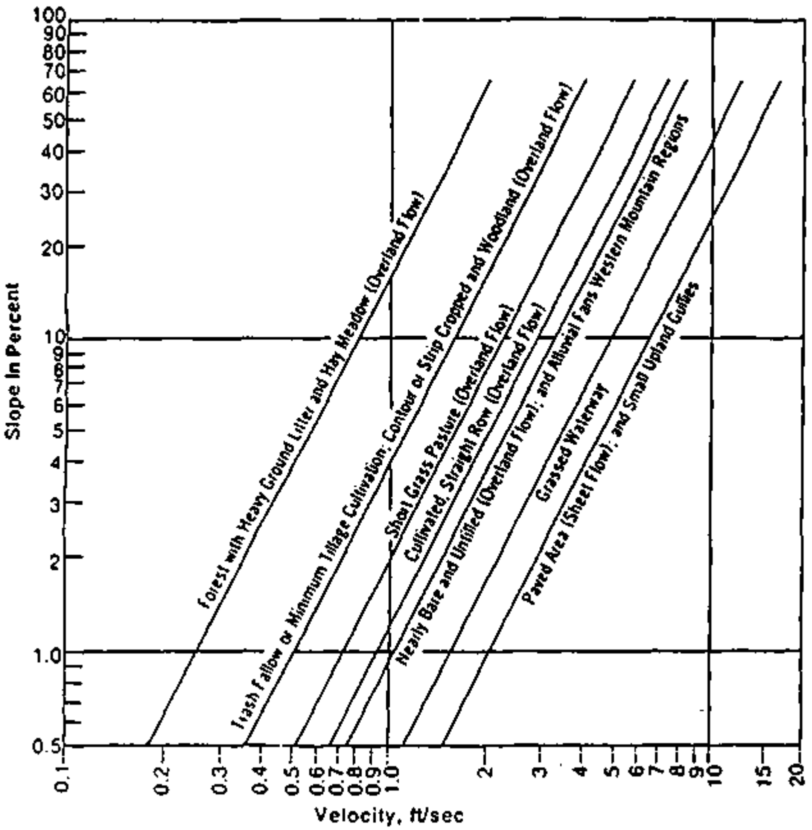


Figure 3.12 Velocities for upland method for estimating travel time for overland flow.

Hydrograph Methods

Generally hydrograph methods are used when dealing with larger drainage areas where the rational method cannot be applied. A detailed explanation of most of these methods is given in *Modern Sewer Design*,[6] published by the American Iron and Steel Institute, Washington, D.C.

Table 3.3 Summary of Runoff Estimation Methods

METHOD	SIZE OF DRAINAGE AREA	REQUIRED INFORMATION	VARIABLES	OUTPUT	APPLICATIONS
RATIONAL METHOD	≤ 20 acres (APWA Spec. Rep. No. 43)	Land Cover Tc IDF Curves	Runoff Coefficient (C)	Peak Flows	Minor System Design
UNIT HYDRO-GRAPH	≤1000 sq mi (only daily rainfall and average daily discharge) Up to 5000 sq mi (extensive records required)	Rainfall and Streamflow Records		Hydrograph	Flood Flows Major System Storage Volumes
SCS UNIT HYDRO-GRAPH	Up to 20 sq mi; if large watershed break down to 20 sq mi sections	Soil Type Rainfall Data Tc	Runoff Curve No. (CN) Accounts for Hydrological Abstractions	Hydrograph	Flood Flows Minor & Major System Storage Volumes
SCS TABULAR METHOD	Up to 20 sq mi; if large watershed break down to 20 sq mi sections	Soil Type Cumulative Rainfall Tc	Runoff Curve No. (CN) Accounts for Hydrological Abstractions	Hydrograph	Flood Flows Major System Storage Volumes
SCS GRAPHICAL METHOD	≤ 20 sq mi	Soil Type Cumulative Rainfall	Runoff Curve No. (CN) Accounts for Hydrological Abstractions	Peak Flow	Flood Peaks Minor & Major System
COMPUTER PROGRAMS	Dependent on capacity of program	Technical Information of Minor System Rainfall	See Users Manual	Hydrographs	Trouble Shooting Design of Minor and Major Systems Storage Volumes
RATIONAL MASS INFLOW	≤ 20 Acres	Landcover IDF Curves Mass Outflow Curve	Runoff Coefficient (C)	Storage Volume	Detention Facility Design
HYDRO-GRAPH METHOD (Volume Determin-ation)	Dependent on source of hydrograph	Inflow Hydrograph Approximate Outflow Hydrograph		Storage Volume Outflow Hydro-graph	Detention Fa-cility Design Reservoir Routing
SCS GRAPHICAL VOLUME METHOD	Dependent on source of peak flow	Peak Inflow Rate Desired Outflow Rate Type of control		Storage Volume	Detention Facility Design

Attachment C1A-4
TR-55 Methodology

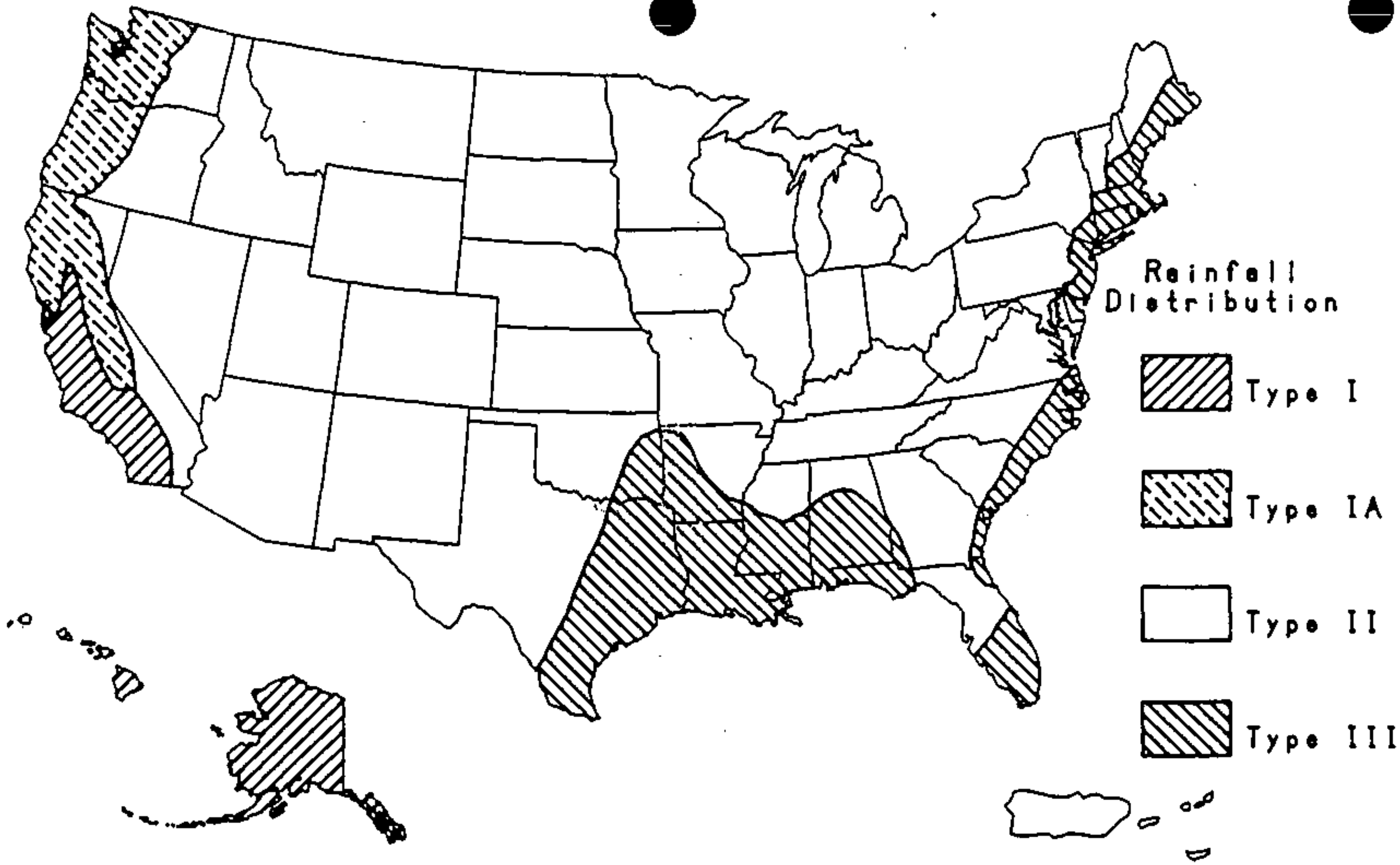
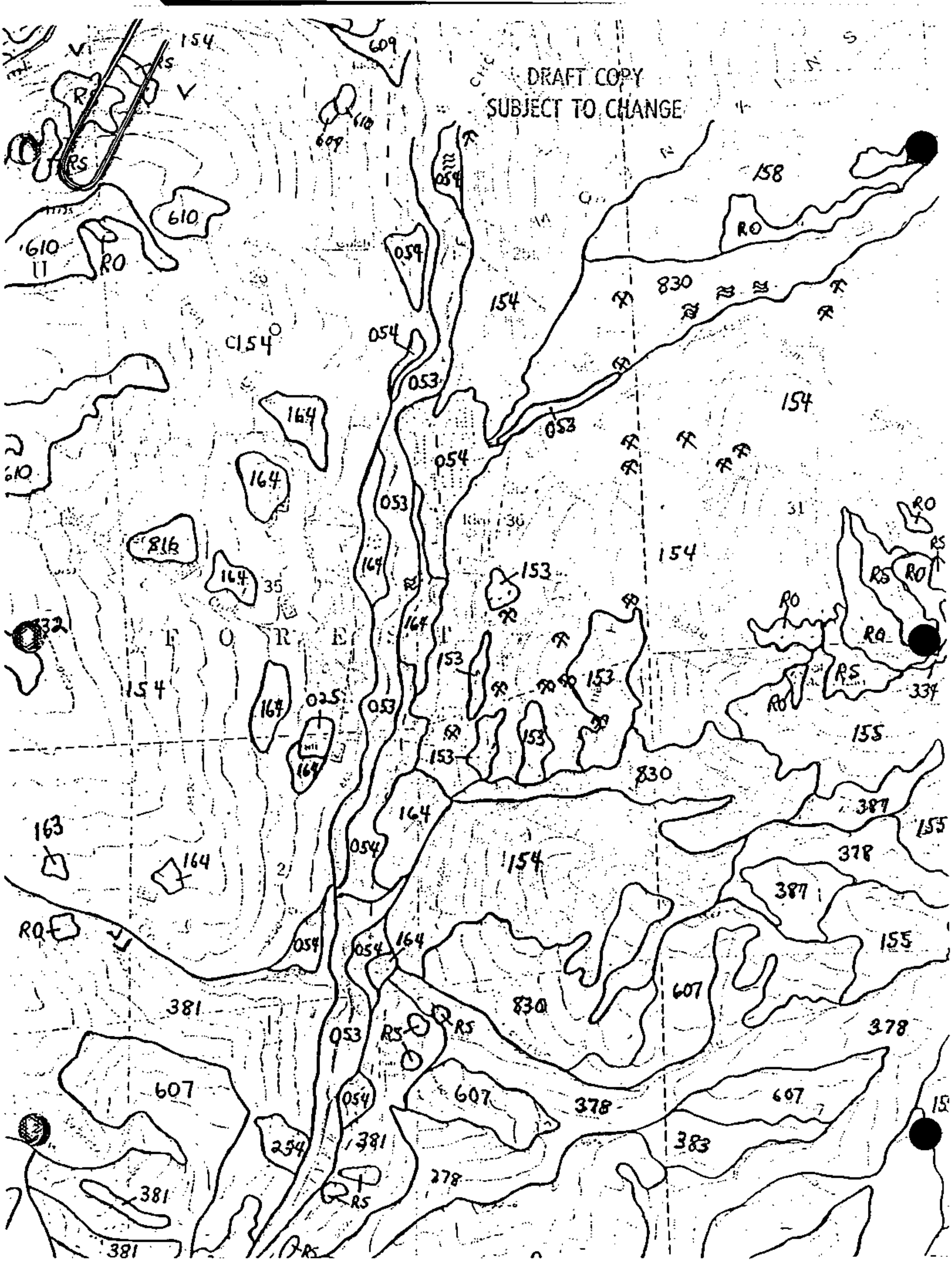


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.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164
381
607
378
830
RS
607
607
378
383
254
381
278
381
381
RS
RO
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337

154--Frisco-Horsethief Complex, 30 to 70 percent slopes, very stony.

Map Unit Description

This map unit is a complex of very deep, well drained soils on mountain sideslopes. This map unit typically has .1 to 3 percent stones on the surface. Elevation is 8,400 to 11,500 feet. The average annual precipitation is 25 to 45 inches, the average annual air temperature is 34 to 38 degrees F, and the average frost-free period is 50 to 70 days. The moisture and temperature regimes are udic and cryic, respectively.

This unit is 60 percent Frisco loam and 25 percent Horsethief loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Brief Soil Description

Frisco loam

The Frisco soil formed in glacial outwash derived dominantly from gneiss, schist and sedimentary rocks. Typically, the surface is covered with a mat of decomposing twigs, needles and bark about 2 inches thick. The surface layer is grayish brown loam about 3 inches thick. The subsurface layer is brown loam about 6 inches thick. The upper part of the subsoil is yellowish brown gravelly loam about 8 inches thick. The next part is brown extremely stony sandy clay loam about 29 inches thick. The lower part is brown extremely stony loam extending to 60 inches or more.

Permeability of the Frisco soil is moderate. Available water capacity is moderate. The hydrologic group is B. Effective rooting depth is 60 inches or more. Runoff is medium to rapid, and the hazard of water erosion is moderate. Content of rock fragments range from 35 to 75 percent in the Bt horizons.

Horsethief loam

The Horsethief soil formed in colluvium and alluvium derived dominantly from sandstone, and volcanic and igneous rocks. Typically, the surface is covered with a mat of needles, twigs and bark about 2 inches thick. The surface layer is pale brown loam about 3 inches thick. The subsurface layer is light yellowish brown fine sandy loam about 19 inches thick. The upper 8 inches of the subsoil is pale brown sandy clay loam. The lower 17 inches is brown very stony clay loam. The substratum to a depth of 60 inches or more is brown very stony clay loam.

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158--Sponsor-Leadville complex 30 to 60 percent slopes.

Map Unit Description

This map unit is a complex of very deep, well drained soils on mountainsides. Elevation is 8,800 to 10,000 feet. The average annual precipitation is 25 to 35 inches, the average annual air temperature is 36 to 42 degrees F, and the average frost-free period is 60 to 90 days. The moisture and temperature regimes are udic and cryic, respectively.

This unit is 60 percent Sponsor loam and 30 percent Leadville loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Brief Soil Description

Sponsor loam

The Sponsor soil formed in glacial outwash, and landslide material derived dominantly from gneiss, schist and sedimentary rocks. Typically, the surface is covered with a mat of organic material about 1 inches thick. The surface layer is dark reddish gray loam about 4 inches thick. The subsurface layer is dark reddish gray loam about 5 inches thick. The upper part of the subsoil is reddish brown clay loam about 13 inches thick. The next part is reddish brown cobbly clay loam about 18 inches thick. The lower part is reddish brown very stony clay loam extending to 48 inches or more.

Permeability of the Sponsor soil is moderately slow. Available water capacity is high. The hydrologic group is B. Effective rooting depth is 60 inches or more. Runoff is rapid, and the hazard of water erosion is moderate. Content of rock fragments range from 5 to 35 percent in the upper part of the subsoil and 20 to 60 percent in the lower part.

Leadville loam

The Leadville soil formed in glacial outwash or slopewash material derived dominantly from gneiss, schist or sedimentary rocks. Typically, the surface is covered with a mat of leaves, needles and partly decomposed organic material about 3 inches thick. The surface layer is brown loam about 1 inch inch thick. The subsurface layer is pinkish gray loam about 3 inches thick. The upper part of the subsoil is pinkish gray very stony clay loam about 14 inches thick. The next part is light reddish brown very cobbly clay loam about 16 inches thick. The lower part is light reddish brown stony clay loam about 34 inches thick. The substratum to a depth of 75 inches or more is light reddish brown very stony sandy clay loam.

Exhibit A-1, continued: Hydrologic soil groups for United States soils

FRECST	C	FULSHEAR	C	GAPCOT	D	GEO	D	GILISPIE	D
FREESTONE	C	FULSTONE	C	GAPO	D	GEE	C	GILLAND	C
FREETOWN	D	FULTON	D	GAPO, DRAINED	C	GEEBURG	C	GILLENDER	D
FREEWATER	B	FULTS	D	GAPPMAYER	B	GEEMORE	C	GILLIAM	C
FREEZENER	B	FULWIDER	D	GARA	C	GEER	B	GILLIGAN	B
FREEZEOUT	B	FUNTER	D	GARBER	B	GEERTSEN	B	GILLS	C
FRELSBURG	D	FUQUAY	B	GARCO	B	GEFO	A	GILLSBURG	C
FREMONT	C	FURNISS	D	GARRUTT	B	GEISEL	B	GILMAN	B
FREN	B	FURSHUR	D	GARCENO	C	GEKE	C	GILMORE	C
FRENCH	C	FURY	D	GARCES	D	GELKIE	B	GILPAR	B
FRENCHCREEK	B	FURY, DRAINED	C	GARCIA	C	GEM	C	GILPIN	C
FRENCHJOHN	C	FUSULINA	D	GARCITAS	C	GEM, STONY	D	GILROY	C
FRENCHMAN	B	FUSUYAR	D	GARCON	C	GEMID	C	GILSTON	B
FRENCHTOWN	D	GAASTRA	C	GARDELLA	D	GEMSON	B	GILT EDGE	D
FRESHWATER	D	GABALDON	B	GARDENA	B	GENAW	D	GIMLETT	B
FRESNO,	D	GABBS	C	GARDINER	A	GENEGRAF	B	GINAT	D
SALINE-ALKALI		GABBVALLY	D	GARDNER'S FORK	B	GENESEE	B	GINEX	D
FRESNO, THICK	C	GABEL	C	GARDNERVILLE	C	GENEVA	B	GINGER	D
SOLUM		GABICA	D	GARDONE	A	GENOA	D	GINI	B
FROWA	B	GABINO	D	GAREY	B	GENOLA	B	GINLAND	D
FREZNIK	D	GACEY	D	GARFAN	B	GENTILLY	D	GINNIS	C
FRIANA	D	GACHADO	D	GARFIELD	C	GENTRY	D	GINSER	C
FRIANT	D	GACIBA	D	GARMILL	D	GEOCONDA	C	GIRARD	D
FRIDLD	C	GADDES	C	GARIPER	C	GEOHROCK	B	GIRARDOT	D
FRIEDLANDER	C	GADDY	A	GARITA	B	GEORGECREEK	B	GIRD	B
FRIEDMAN	C	GADSDEN	D	GARLAND	B	GEORGETOWN	D	GIST	D
FRIENDS	C	GADSDEN, WET	C	GARLET	B	GEORGEVILLE	B	GITAKUP	C
ENDSHIP	A	SUBSTRATUM		GARLOCK	B	GEORGIA	C	GITAN	D
ES	D	GADWELL	C	GARMON	C	GEPFORD	D	GIVIN	C
IZSLAND	B	GAGEBY	B	GARMORE	B	GEPP	B	GLACIERCREEK	A
FRIJOLES	B	GAGETOWN	B	GARNEL	D	GEPPERT	C	GLADDEN	B
FRINDLE	C/	GAGIL	B	GARNER	D	GERALD	D	GLADEL	D
FRINES	C	GAHEE	B	GARNES	B	GERBER	D	GLADEVILLE	D
FRIO	B	GAIE	D	GARO	D	GERDRUM	D	GLADEWATER	D
FRIONA	C	GAILA	B	GARR	D	GERING	B	GLADSTONE	B
FRISTON	C	GAINES	C	GARRETSON	B	GERLACH	D	GLADWIN	A
FRIPP	A	GAINESBORO	C	GARRETT	B	GERLANE	B	GLASGOW	C
FRISCO	B	GAINESVILLE	A	GARRISON	B	GERLE	B	GLASSNER	D
FRISITE	B	GALATA	D	GARROCHALES	D	GERMANTOWN	B	GLEAN	B
FRITZ	B	GALBRETH	D	GARSID	C	GERMANY	B	GLEASON	B
FRIZZELL	C	GALCHUTT	C	GARTON	C	GERMER	C	GLEBE	C
FROBERG	D	GALE	B	GARVESON	C	GERONI	B	GLEN	B
FRODO	D	GALEN	B	GARVIN	D	GERRARD	C	GLENBAR	B
FROHMAN	C	GALEPPI	B	GARWIN	B/D	GERRARD, DRAINED	B	GLENBAR, WET	C
FROLIC	B	GALESTINA	C	GARZA	B	GERST	D	GLENBERG	B
FROLIC,	C	GALESTOWN	A	GARZONA	D	GESSIE	B	GLENBLAIR	C
ELEVATION<8000		GALEY	B	GAS CREEK	D	GESSNER	B/D	GLENBROOK	D
FROLIC, FLOODED	C	GALILEE	C	GASCONADE	D	GESTRIN	B	GLENCARB	B
FRONDORF	B	GALISTEO	C	GASIL	B	GETAWAY	B	GLENCARB, WET,	C
FRONTENAC	B	GALISTEO,	C	GASQUET	B	GETCHELL	C	SALINE	
FRONTIER	C	SALINE-ALKALI		GASSAWAY	D	GETRAIL	D	GLENCOE	B/D
FRONTON	D	GALLAND	D	GASSVILLE	C	GETTYS	C	GLENCOE, PONDED	D
FROST	D	GALLATIN	C	GASTON	C	GETZVILLE	D	GLENDALE	B
FROZARD	C	GALLEGOS	B	GAT	B	GEWTER	C	GLENDALE, WET	C
FRUITA	B	GALLEN	B	GATES	B	GEYSEN	C	GLENDALE, RARELY	C
FRUITFIELD	A	GALLIA	B	GATESON	C	GIBBLER	C	FLOODED	
FRUITHURST	C	GALLIME	B	GATEVIEW	B	GIBBON	B	GLENDERSON	B
FRUITLAND	B	GALLION	B	GATEWAY	C	GIBBONSCREEK	C	GLENDIVE	B
FRUITLAND,	C	GALLMAN	B	GATEWOOD	C	GIBBS	D	GLENDORA	A/D
MODERATELY WET		GALLUP	B	GATLIN	B	GIENEY	C	GLENEDEN	D
FRUITLAND, WET	C	GALOO	C/D	GATOR	D	GIBSONVILLE	D	GLENELG	B
FRYE	C	GALT	D	GATTON	B	GIBWELL	C	GLENFORD	C
FRYEBURG	B	GALVA	B	GAULDY	B	GIDEON	C	GLENHALL	B
FT. DRUM	C	GALVESTON	A	GAULEY	C	GIELOW	C	GLENHAM	B
FT. GREEN	D	GALVEZ	C	GAVEL	C	GIFFORD	D	GLENMEN	B
FUBAR	C	GALVIN	D	GAVILAN	C	GIGGER	C	GLENMORA	C
FUBBLE	D	GALWAY	B	GAVINS	D	GILA	B	GLENNALLEN	C
FUEGO	C	GAMBLER	B	GAVIOTA	D	GILBERT	D	GLENOMA	B
FUEGOSTA	D	GAMBOA	B	GAY	B/D	GILBOA	B	GLENPOOL	A
FUERA	C	GAMGEE	C	GAYLESVILLE	D	GILBY	B	GLENRIO	D
FUGAWEE	B	GAMAGO	D	GAYLORD	C	GILCHRIST	A	GLENROSE	B
FUGHES	C	GANCE	C	GAYNOR	C	GILCO	B	GLENROSS	D
FULCHER	C	GANDO	D	GAYVILLE	D	GILCREST	B	GLENSTED	D
FULDA	C/D	GANIS	D	GAZELLE	D	GILEAD	C	GLENTON	B
FULLAM	C	GANNETT	D	GAZOS	C	GILES	B	GLENTON, WET	C
FULLER	D	GANSNER	C	GAZWELL	C	GILFORD	B/D	GLENTOSH	A
FULLERTON	B	GANSNER, PONDED	D	GEARHART	A	GILFORD,	D	GLENVIEW	B
FULMER	D	GANT	B	GEARY	B	STRATIFIED		GLENVILLE	C
FULMER, DRAINED	C	GAPBUTTE	B	GEBSON	B	SUBSTRATUM		GLENTON	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
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Exhibit A-1, continued: Hydrologic soil groups for United States soils

LAMKIN	B	LARIAT	B	LAVINA	D	LEETONIA	C	LEW	B
LAMO	C	LARIM	B	LAVON	C	LEEVAN	C	LEWBEACH	C
LAMOILLE	B	LARIMER	B	LAWAI	B	LEFOR	B	LEWDLAC	D
LAMONDI	B	LARIOSCAMP	D	LAWEN	B	LEGALL	B	LEWIS	D
LAMONI	C	LARKIN	B	LAWET	B/D	LEGAULT	D	LEWISBERRY	B
LAMONT	B	LARKSON	C	LAWET,	B	LEGGETT	C	LEWISBURG	C
LAMONTA	D	LARMINE	C	SALINE-ALKALI		LEGLER	B	LEWISTON	C
LAMOOSE	D	LAROQUE	B	LAWLER	B	LEGORE	B	LEWISVILLE	B
LAMOTTE	B	LAROSE	D	LAWNDALE	B	LEHEW	C	LEWKALB	C
LAMOURE	C	LARRUPIN	B	LAWNWOOD	B/D	LEHIGH	C	LEX	B
LAMPASAS	D	LARRY	D	LAWNWOOD,	D	LEHMANS	D	LEXINGTON	B
LAMPHIER	B	LARRY, DRAINED	C	DEPRESSIONAL		LEHR	B	LEXTON	B
LAMPSHIRE	D	LARSON	D	LAWRENCE	C	LEICESTER	C	LEYBA	B
LAMSON	B/D	LARTON	A	LAWRENCEVILLE	C	LEIOL	C	LEYDEN	C
LANARK	B	LARUE	A	LAWSHE	D	LEIGHCAN	B	LIBBINGS	D
LANCASTER	B	LARUSH	B	LAWSON	C	LEILEHUA	B	LIBEG	B
LANCE	B	LARVIE	D	LAWTHER	D	LEISY	B	LIBERAL	D
LAND	C	LAS	C	LAWTON	C	LELA	D	LIBORY	A
LAND, DRAINED	B	LAS ANIMAS	C	LAWYER	B	LELAND	B	LIBRARY	D
LANDAVASO	B	LAS FLORES	D	LAX	C	LEMAH	A	LIBUSE	C
LANDCO	C	LAS LUCAS	B	LAXAL	B	LEMBOS	C	LICHA	B
LANDER	C	LAS POSAS	C	LAXTON	C	LEMCO	C	LICK	B
LANDES	B	LAS VEGAS	D	LAYCOCK	B	LEMERT	D	LICKDALE	D
LANDLOW	C	LASA	A	LAYOINT	C	LEMETA	D	LICKING	C
LANDMAN	B	LASALLE	D	LAYTON	A	LEMING	C	LICKSKILLET	D
LANDSEND	C	LASAUSES	D	LAYVIEW	D	LEMITAR	D	LIDAN	C
LANE	C	LASCO	B	LAZAN	D	LEMM	B	LIDDELL	B/D
LANESBORO	C	LASIL	D	LAZEAR	D	LEMOLO	D	LIDDIEVILLE	B
LANEXA	D	LASKA	B	LE BAR	B	LEMOND	B/D	LIDY	B
LANEY	B	LASSEL	C	LE SUEUR	B	LEMONEX	C	LIEBERMAN	B
LANG	C	LASSEN	D	LEA	C	LEMOORE	C	LIEN	D
LANGFORD	C	LASSITER	B	LEADER	B	LEMPIRA	B	LIESNOI	D
LANGHEI	B	LASTANCE	B	LEADORE	B	LEN	C	LIGGET	B
LANGLADE	B	LATAH	D	LEADPOINT	C	LENA	A/D	LIGHTNING	D
LANGLOIS	D	LATAM, HIGH	C	LEADVALE	C	LENA, FLOODED	D	LIGNUM	C
LANGOLA	B	RAINFALL, DRAINED		LEADVILLE	B	LENAPAH	D	LIGON	D
LANGRELL	B	LATAM, DRAINED	C	LEAF	D	LENAWEE	B/D	LIGURTA	B
LANGSPRING	B	LATAMCO	C	LEAFRIVER	A/D	LENAWEE, PONDED	D	LIHEN	A
LANGSTON	B	LATAMCO, WET	D	LEAKU	C	LENBERG	C	LIHUE	B
LANGTRY	D	LATANIER	D	LEAGUEVILLE	B/D	LENNEP	C	LIKES	A
LANIER	A	LATCH	A	LEAKSVILLE	D	LENOIR	D	LILAH	A
LANIGER	B	LATENE	B	LEAL	D	LENZ	B	LILBERT	B
LANIGER, GRAVELLY	C	LATES	C	LEALANDIC	D	LENZ, STONY	C	LILBOURN	B
LANKBUSH	B	LATEX	C	LEANNA	D	LENZ, VERY STONY	C	LILLINGS	B
LANKIN	C	LATHAM	D	LEANTO	D	LENZBURG	B	LILLINGTON	B
LANKTREE	C	LATHER	D	LEAPS	C	LEO	A	LILLYLANDS	C
LANOAK	B	LATHROP	B	LEATHAM	C	LEOLA	B	LILTEN	C
LANONA	B	LATIGO	B	LEATHERMAN	D	LEON	B/D	LILY	B
LANSDALE	B	LATINA	D	LEAVENWORTH	C	LEONARD	D	LIM	C
LANSDOWNE	C	LATIUM	D	LEAVERS	B	LEONARDO	B	LIMA	B
LANSING	B	LATOM	D	LEAVITT	B	LEONARDTOWN	D	LIMBER	B
LANTERN	B	LATONIA	B	LEAVITTVILLE	B	LEONI	B	LIMEKILN	D
LANTIS	B	LATOUCHE	D	LEBAM	B	LEQUIEU	D	LIMERICK	C
LANTON	D	LATOUR	B	LEBANON	C	LERDAL	C	LIMERIDGE	D
LANTON, LOW	C	LATOURELL	B	LEBEAU	D	LERDO	C	LIMKING	B
PRECIPITATION		LATTAS	D	LEBEC	B	LEROY	B	LIMON	C
LANTONIA	B	LATTY	D	LEBO	B	LERROW	C	LIMON, WET	D
LANTRY	B	LAUDERDALE	D	LEBSACK	C	LESHARA	B	LIMONES	B
LANTZ	D	LAUDERHILL	B/D	LECK KILL	B	LESHO	C	LIMPIA	C
LANVER	C	LAUFER	D	LECRAG	D	LESLIE	D	LINCO	B
LANYON	C/D	LAUGENOUR, LOAMY	C	LEDFORD	B	LESON	D	LINCOLN	A
LAP	D	SUBSTRATUM		LEDGEFORK	A	LESPATE	C	LINDAAS	C/D
LAPARITA	C	LAUGENOUR, SILTY	B	LEDMOUNT	D	LESTER	B	LINDALE	C
LAPDUN	B	SUBSTRATUM		LEDOW	B	LESWILL	B	LINDELL	C
LAPED	D	LAUGENOUR, DRAINED	B	LEDRU	D	LETA	C	LINDEN	B
LAPEER	B	LAUGHLIN	C	LEDUB	B	LETCHER	D	LINDER	B
LAPHAM	A	LAUMAIA	B	LEDWITH	B/D	LETHA	C	LINDLEY	C
LAPINE	A	LAUREL	D	LEE	D	LETHENT	D	LINDRITH	B
LAPLATTA	C	LAURELWOOD	B	LEEBENCH	B	LETNEY	A	LINDSIDE	C
LAPON	D	LAUREN	B	LEEDS	C	LETON	D	LINDSTROM	B
LAPORTE	D	LAURENTZEN	B	LEEFIELD	C	LETORT	B	LINDY	C
LAPOSA	C	LAVACREEK	B	LEEKO	C	LETRI	B/D	LINE	B
LAPWAI	B	LAVALLEE	B	LEEKO, WARM	B	LETTIA	B	LINEVILLE	C
LARAND	B	LAVATE	B	LEELANAU	A	LEVASY	C	LINGANORE	B
LARCHMOUNT	B	LAVEAGA	C	LEEMONT	D	LEVELTON	D	LINHART	A
LARDELL	C	LAVEEN	B	LEEPER	D	LEVELTON, DRAINED	C	LININGER	C
LAREDO	B	LAVENTANA	B	LEERAY	D	LEVERETT	C	LINKER	B
LARES	C	LAVERKIN	C	LEESBURG	B	LEVIATHAN	B	LINKUP	D
LARGO	B	LAVIC	B	LEESVILLE	B	LEVY	D	LINKVILLE	B

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

HESCH	B	HILLSBORO	B	HOLDERMAN	C	HOODVIEW	B	HOWELL	C
HESPER	B	HILLSDALE	B	HOLDERNESS	C	HOOGDAL	C	HOWLAND	C
HESPERIA	B	HILLTO	B	HOLDINGFORD	C	HOOKS	B	HOWSON	C
HESPERUS	B	HILLWOOD	B	HOLDREGE	B	HOOKSAN	A	HOYE	B
HESSEL	B/D	HILMAR	D	HOLILLIPAH	A	HOOKTON	C	HOYLETON	C
HESSELBERG	D	HILMAR, DRAINED	B	HOLLAND	B	HOOLEHUA	B	HOYPUS	A
HESSELTINE	B	HILMOE	C	HOLLANDLAKE	B	HOOLY	C	HOYTVILLE	C/D
HESSING	B	HILO	A	HOLLINGER	B	HOOPAL	D	HUACHUCA	D
HESSLAN	C	HILOLO	D	HOLLIS	C/D	HOOPER	D	HUALAPAI	C
HESSON	C	HILT	B	HOLLISTER	D	HOOPESTON	B	HUE	B
HETERVA	C	HILTON	B	HOLLOMAN	D	HOOPLITE	D	HUBBARD	A
HETTINGER	C/D	HINCKLEY	A	HOLLOMEX	B	HOOSAN	B	HUBBARDTON	D
HEUSSER	C	HINDES	C	HOLLOW	C	HOOSEGOW	B	HUBBELL	B
HEUVELTON	C	HINESBURG	C	HOLLOWAY	B	HOOSIC	A	HUBERLY	D
HEWITT	D	HINKER	C	HOLLOWTREE	C	HOOSIERVILLE	C	HUBERT	B
HEXT	B	HINKLE	D	HOLLY	B/D	HOOSINBIM	B	HUBLERSBURG	B
HEYDER	B	HINMAN	C	HOLLY, PONDED	D	HOOT	D	HUCKLEBERRY	C
HEYOLAUFF	B	HINSDALE	D	HOLLY SPRINGS	D	HOOTEN	D	HUCKLEBERRY, HIGH	B
HEYTOU	B	HIRAMSBURG	C	HOLLYWELL	B	HOPCO	C	RAINFALL	
HEZEL	B	HIRIDGE	D	HOLLYWOOD	D	HOPDRAW	A	HUDNUT	B
HI VISTA	C	HIRSCHDALE	C	HOLMAN	A	HOPEKA	D	HUDSON	C
HIARC	C	HISEGA	C	HOLMDEL	C	HOPKINS	B	HUECO	C
HIBAR	C	HISKEY	B	HOLMES	B	HOPLAND	B	HUEL	A
HIBBARD	C	HISLE	D	HOLOMAN	B	HOPLEY	B	HUENEME	C
HIBBING	C	HITCHCOCK	B	HOLOMUA	B	HOPSONVILLE	C	HUENEME,	B
HIBERNIA	C	HITILO	A	HOLOPAW	B/D	HOQUIAM	B	MODERATELY WET	
HIBRITEN	B	HITT	B	HOLOPAW,	C	HORD	B	HUENEME, DRAINED	B
HICKMAN	B	HIVAL	D	DEPRESSIONAL		HOREB	C	HUERFANO	D
HICKORY	C	HIWAN	D	HOLOPAW,	D	HOREB, GRAVELLY	B	HUEY	D
HICKS	B	HIWASSEE	B	FREQUENTLY		SUBSTRATUM		HUFFINE	B
HICKSVILLE	B	HIWOOD	A	FLOODED		HORNELL	D	HUFFMAN	B
HICKSVILLE,	C	HIXTON	B	HOLSINE	B	HORNING	B	HUFFTON	B
BEDROCK		HOADLY	C	HOLSTEIN	B	HORNITOS	D	HUGGINS	C
SUBSTRATUM		HOBACKER	B	HOLSTON	B	HORNSBY	C	HUGHES	B
HICOTA	B	HOBAN	B	HOLT	B	HORNSVILLE	C	HUGHESVILLE	C
HIDALGO	B	HOBBS	B	HOLTER	B	HORROCKS	B	HUGO	B
HIDATSA	B	HOBCAW	D	HOLTLE	B	HORSECAMP	D	HUGUS	B
HIDEAWAY	D	HOBE	A	HOLTON	C	HORSERIDGE	B	HUGUSTON	D
HIDEWOOD	B/D	HOBERG	C	HOLTVILLE	C	HORSESHOE	B	HUICHICA	C
HIERRO	B	HOBIT	C	HOLYOKE	C/D	HORSETHIEF	B	HUICHICA, PONDED	D
HIGGINS	D	HOBO	D	HOMA	C	HORSLEY	D	HUIKAU	A
HIGGINSVILLE	C	HOBOG	D	HOME CAMP	C	HORST	B	HUKILL	C
HIGH GAP	C	HOBONNY	D	HOMELAKE	B	HORTONVILLE	B	HULETT	B
HIGHAMS	D	HOBSON	C	HOMELAND	C	HOSKIN	C	HULLS	C
HIGHBANK	C	HOBUCKEN	D	HOMER	B	HOSKINNINI	D	HULLT	B
HIGHCAMP	B	HOCAR	D	HOMESTAKE	C	HOSLEY	D	HULUA	D
HIGHFIELD	B	HOCHHEIM	B	HOMESTEAD	B	HOSMER	C	HUM	B
HIGHHORN	B	HOCKINSON	D	HOMEWOOD	C	HOSSICK	B	HUMACAO	B
HIGHMORE	B	HOCKINSON,	C	HOMME	C	HOSTAGE	B	HUMATAS	C
HIGHPOINT	D	MODERATELY WET		HOMME, MODERATELY	B	HOT LAKE	C	HUMBARGER	B
HIGHROCK	D	HOCKINSON, DRAINED	B	WET		HOTAW	C	HUMBIG	C
HIGHTOWER	C	HOCKLEY	C	HOMOSASSA	D	HOTCREEK	D	HUMBIRD	B
HIGHWOOD	C	HOCKLEY, GRADED	D	HONAUNAU	C	HOTEL	C	HUMBOLDT	D
HIHIMANU	B	HODA	C	HONCUT	B	HOTSPRINGS	B	HUMBOLDT,	B
HIIBNER	C	HODEDO	C	HONDALE	D	HOUDEK	B	MODERATELY WET,	
HIKO PEAK	B	HODENPYL	B	HONDOHO	B	HOUGH	B	SALINE-ALKALI	
HIKO SPRINGS	B	HODGE	A	HONEOYE	B	HOUGHTON	A/D	HUMBOLDT,	B
HILAIRE	B	HODGINS	B	HONEYDEW	C	HOUGHTON, PONDED	D	MODERATELY WET,	
HILAND	B	HODGSON	C	HONEYGROVE	D	HOUGHTONVILLE	C	SALINE	
HILDEBRECHT	C	HOEHNE	A	HONEYJONES	B	HOUK	C	HUMBOLDT, DRAINED,	B
HILDRETH	D	HOFFLAND	D	HONEYVILLE	C	HOULA	B	STRONGLY SALINE	
HILEA	D	HOFFMANVILLE	C	HONKER	D	HOULKA	D	HUMBOLDT, DRAINED,	B
HILES	B	HOFFSTADT	B	HONLAK	C	HOURGLASS	B	NONSALINE	
HILGER	B	HOFLY	C	HONLAK, DRAINED	B	HOUSE MOUNTAIN	D	HUMBOLDT,	B
HILGRAVE	B	HOGADERO	B	HONLU	B	HOUSER	D	MODERATELY WET	
HILIGHT	D	HOGANSBURG	B	HONN	B	HOUSEROCK	D	HUMBOLDT, DRAINED	B
HILINE	D	HOGBACK	C	HONOBIA	C	HOUSTAKE	C	HUMDUN	B
HILLBRICK	D	HOGG	C	HONOKAA	A	HOUSTON	D	HUME	C
HILLCO	B	HOGMALAT	D	HONOLUA	B	HOUSTON BLACK	D	HUMESTON	C/D
HILLEMANN	C	HOGRIS	B	HONOMANU	A	HOVDE	D	HUMKER	C
HILLERY	C	HOH	B	HONOMEGAM	A	HOVEN	D	HUMMINGTON	C
HILLET	B/D	HOHMANN	C	HONOULIULI	B	HOVENWEEP	C	HUMPHREYS	B
HILLFIELD	B	HOKO	C	HONTAS	B	HOVERT	D	HUMPTULIPS	B
HILLGATE	D	HOLBORN	C	HONTOON	B/D	HOVEY	C	HUMSKEL	C
HILLIARD	B	HOLBROOK	B	HONUAULU	A	HOWARD	A	HUN	B
HILLIARD,	C	HOLCOMB	D	HOOD	B	HOWARDSVILLE	A	HUNCHBACK	D
MODERATELY WELL		HOLDAWAY	D	HOODLE	B	HOWCAN	B	HUNDRAW	D
DRAINED		HOLDEN	B	HOODOO	D	HOWCREE	C	HUNEWILL	B
HILLON	C	HOLDER	B	HOODSPORT	C	HOWE	C	HUNGRY	C

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Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

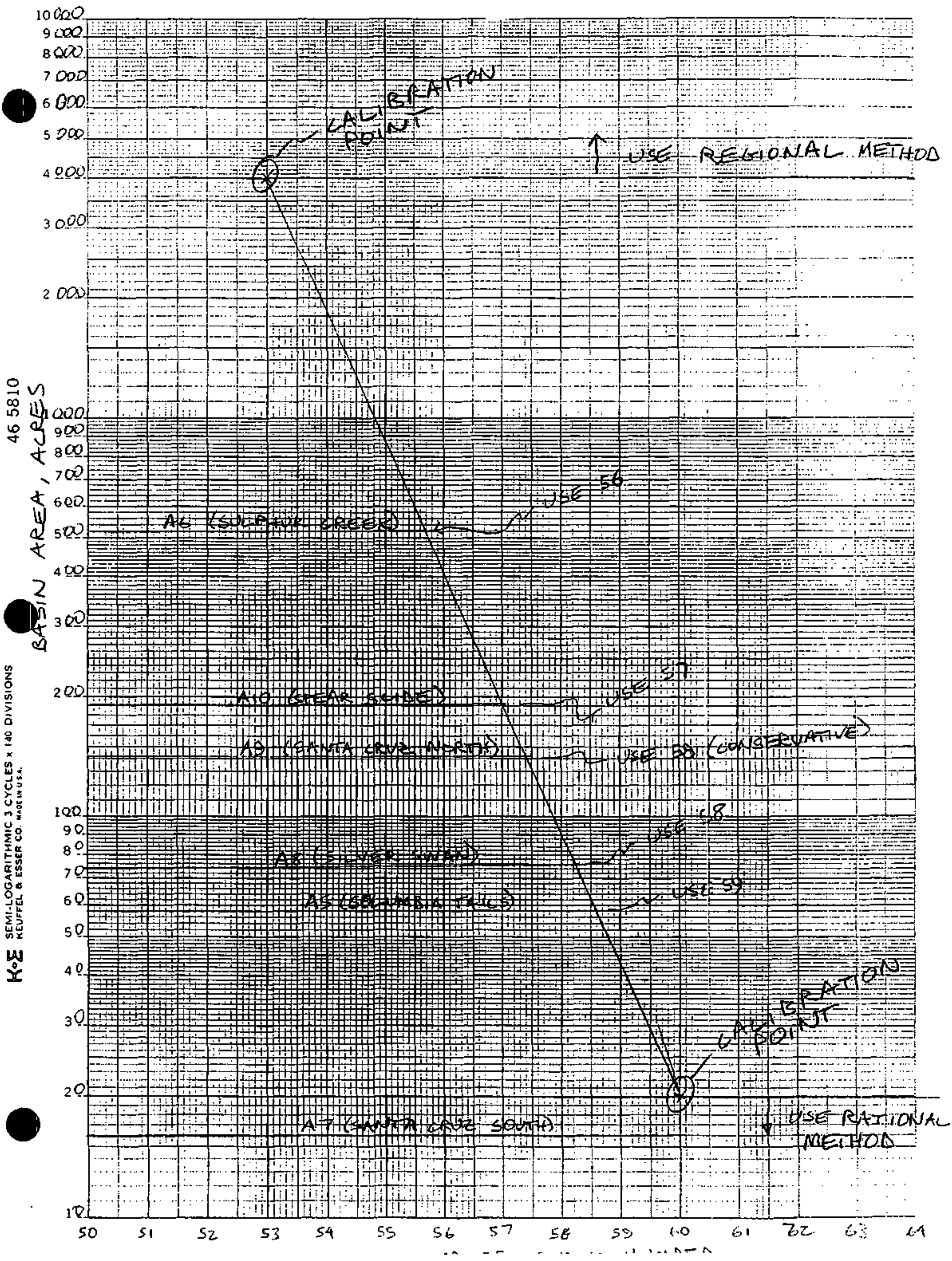
[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.



BASIN AREA, ACRES
10 000
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
CALIBRATION POINT
USE REGIONAL METHOD
A6 (SULPHUR CREEK)
USE 56
A10 (BEAR SLIDE)
USE 57
A9 (SANTA CRUZ NORTH)
USE 58 (CONSERVATIVE)
A8 (SILVER SWAN)
USE 58
A5 (COLUMBIA TAILS)
USE 59
CALIBRATION POINT
A7 (SANTA CRUZ SOUTH)
USE RATIONAL METHOD
46 5810
K+E SEMI-LOGARITHMIC 3 CYCLES x 140 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Attachment C1A-5
Regional Regression Methodology

COLORADO WATER CONSERVATION BOARD
COLORADO DEPARTMENT OF NATURAL RESOURCES

TECHNICAL MANUAL NO. 1

MANUAL FOR ESTIMATING FLOOD CHARACTERISTICS OF NATURAL-FLOW STREAMS IN COLORADO

By Jerald F. McCain *and* Robert D. Jarrett

U.S. Geological Survey

Prepared in cooperation with the

U.S. GEOLOGICAL SURVEY

Colorado Water Conservation Board
1845 Sherman Street
Denver, Colorado 80203

1976

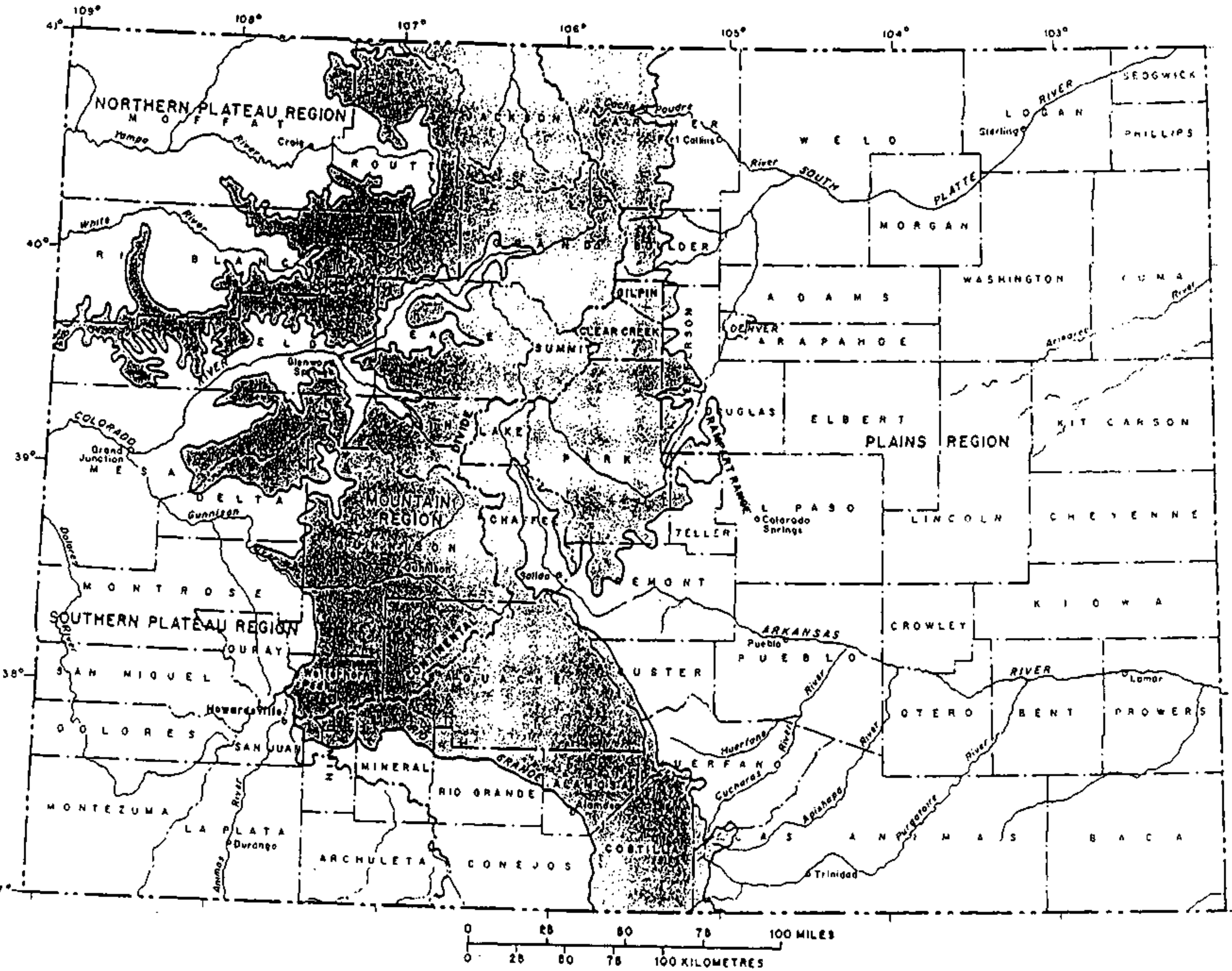


Figure 2.--Flood-characteristic regions in Colorado.

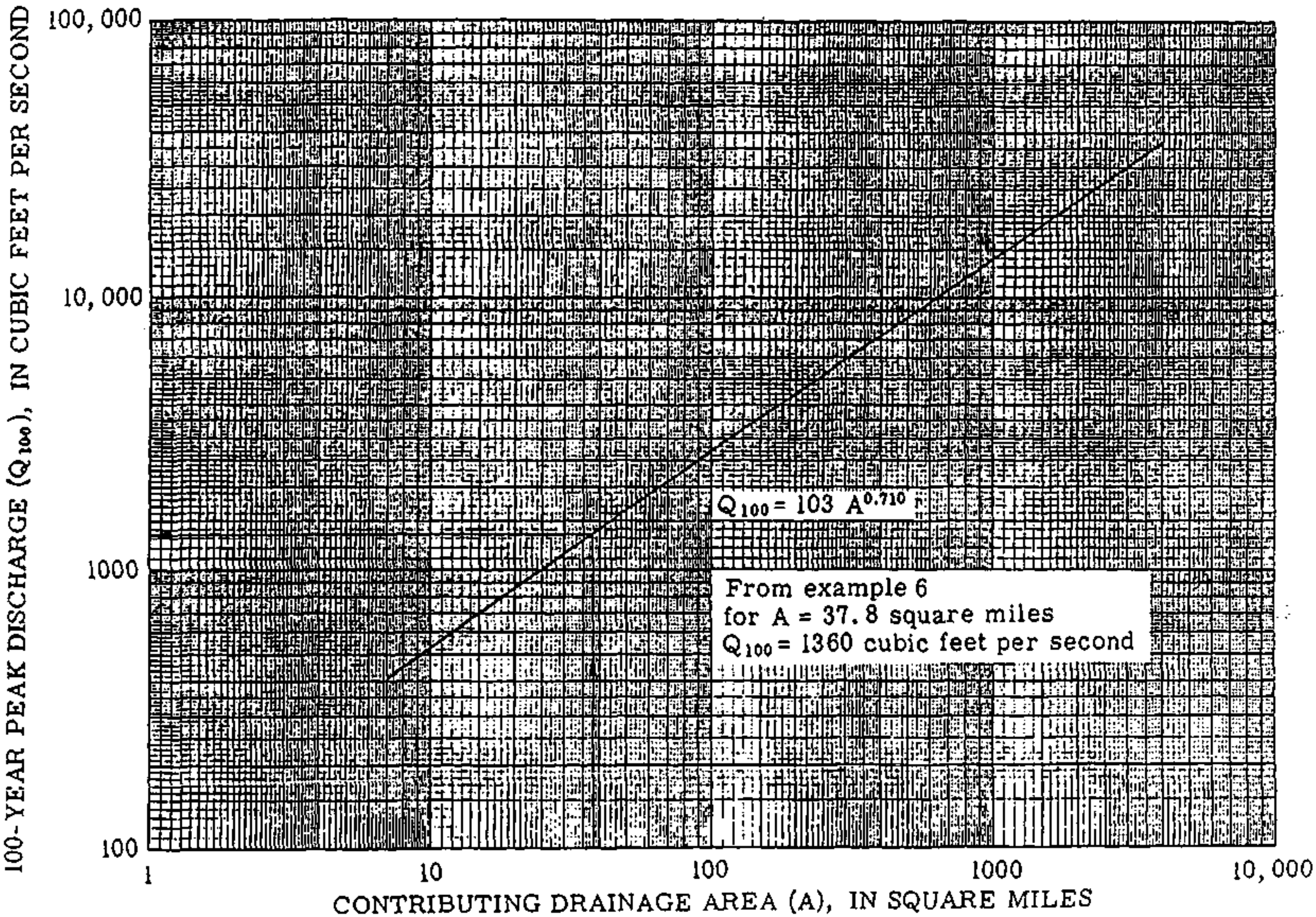


Figure 9.--Relation of 100-year peak discharge to contributing drainage area for the Southern Plateau Region.

Attachment C1A-6
Basin Flow Results

Summary of Results

Job:	101.9502
Project:	Rico
By:	ACJ
Location:	Sulphur Creek
Basin:	A6

Regional Regression Analyses

Basin Area:	521 acres	0.81 sq. mi.
Q:	89.0 cfs	

TR-55 Method

Q:	101.0 cfs

Rational Method

Q:	173.5 cfs

15:20:29 07/31/95 C:\ARCO\RICO\A6HYDRO.WB1

GRAPHICAL PEAK DISCHARGE METHOD Version 2.00

Project : Rico Technical Services User: ACJ Date: 07-31-95
County : Dolores State: CO Checked: ____ Date: _______
Subtitle: Basin A6

Data: Drainage Area : 521 Acres
Runoff Curve Number : 56
Time of Concentration: 0.73 Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1
Frequency (yrs)	100
24-Hr Rainfall (in)	3.75
Ia/P Ratio	0.42
Runoff (in)	0.47
Unit Peak Discharge (cfs/acre/in)	0.409
Pond and Swamp Factor 0.0% Ponds Used	1.00
Peak Discharge (cfs)	101

Time of Concentration by TR-55 Methodology

Job:	101.9502
Project	Rico
By:	ACJ
Location:	Sulphur Creek
Basin:	A6

Storm analyzed: 100 yr 6 hr

A. Sheet Flow

1. Surface description	Woods			
2. Manning's RC (n)	0.4			
3. Flow length, L	300	ft (MAX IS 300)		
4. rainfall	2.6	in	Suggested:	2.6 in
Beginning Elevation	12071			
Ending Elevation	11960			
5. Land slope, s	0.37	ft/ft		
6. Tt = 0.007(nl)^.8/(p2^.5*s^.4)	0.298	hr	17.9 min	

B. Shallow Concentrated Flow

7. Surface description	Unpaved		
8. Flow length, L	1000	ft	
Beginning Elevation	11960		
Ending Elevation	11200		
9. Watercourse slope, s	0.76	ft/ft	
10. Average Velocity, V	2.3	ft/s	
11. Tt= L/(3600V)	0.121	hr	7.2 min

C. Channel Flow

Q (base flow from u/s subarea)	0			
Q (calculated - guess on first iteration)	25.25	(use about 1/4 of calculated Q at end of channel):		41.7 cfs
Q (total)	25.25			
Q (adjust flow area so to match this Q to a	25.3			
12. Cross section flow area, a	2.7	ft2		
13. Wetted perimeter, pw	5.2	ft (calculated)	Assumes V channel, 2H:1V)	
14. Hydraulic radius, r=a/pw	0.52	ft		
Beginning Elevation	11200			
Ending Elevation	8700			
15. Channel slope, s	0.24			
16. Mannings RC, n	0.05			
17. V=1.49[(r^2/3)s^.5]/n	9.38	ft/s		
18. Flow Length	10500	ft		
19. Tt= L/3600V	0.31	hr	18.7 min	

D. Subarea Tc

20. Tt	0.73	hr	43.8 min

E. Basin Statistics

Elevation Drop:	3371	ft
Horizontal Flow Length:	11800	ft

file SH1-1

Job:	101.9502
Project:	Rico Technical Services
By:	ACJ

Re:	Design Q, 100 yr, 6 hour design storm
Location:	Sulphur Creek
Basin:	A6

Inputs

Storm Recurrence Interval	100	yrs
Runoff Coefficient (C)	0.10	
Basin Area:	521	acres
Maximum Length of water travel:	11800	ft
TR-55 calculated time of concentration:	41.1	min
Time of concentration factor:	2.0	(for use in adjusting Kirpich formula)

Rainfall Intensity-Duration Curve

Duration (D, hrs)	(min)	I(in/hr)	dI/dD
0.083	5	6.75	-17.76
0.167	10	5.27	-9.96
0.250	15	4.44	-5.44
0.500	30	3.08	-2.26
1.000	60	1.95	-2.26

Work Area

Antecedent Precipitation Factors

Recurrence Interval (yrs)	Ca		
		Ikey	0.5
		Ibase	3.08
2	1	Idelta	-2.26
10	1		
25	1.1		
50	1.2		
100	1.25		

Results

Height drop of water travel:	3371 ft		
Antecedent Precipitation Factor (Ca)	1.25		
C * Ca	0.13		
Basin Slope:	28.6%		
Time of Concentration (Tc):	0.58 hrs	34.5 min	(Kirpich formula)
Tc for analysis:	0.68 hrs	41.1 min	(max of Kirpich or TR-55)
Average Water Velocity:	5.7 ft/s		
Intensity (I)	2.7 in/hr		
Q (=CCaIA)	173.5 cfs		

Time of Concentration by TR-55 Methodology

Job: 101.9502
Project: Rico
By: ACJ
Location: Sulphur Creek
Basin: A6

Storm analyzed: 100 yr 6 hr

A. Sheet Flow

1. Surface description	Woods			
2. Manning's RC (n)	0.4			
3. Flow length, L	300	ft (MAX IS 300)		
4. rainfall	2.7	in	Suggested:	2.7 in
Beginning Elevation	12071			
Ending Elevation	11960			
5. Land slope, s	0.37	ft/ft		
6. Tt = 0.007(nl)^.8/(p2^.5*s^.4)	0.292	hr	17.5 min	

B. Shallow Concentrated Flow

7. Surface description	Unpaved		
8. Flow length, L	1000	ft	
Beginning Elevation	11960		
Ending Elevation	11200		
9. Watercourse slope, s	0.76	ft/ft	
10. Average Velocity, V	2.3	ft/s	
11. Tt= L/(3600V)	0.121	hr	7.2 min

C. Channel Flow

Q (base flow from u/s subarea)	0			
Q (calculated - guess on first iteration)	43.4	(use about 1/4 of calculated Q at end of channel):		43.4 cfs
Q (total)	43.4			
Q (adjust flow area so to match this Q to abo	43.5			
12. Cross section flow area, a	4.1	ft2		
13. Wetted perimeter, pw	6.4	ft (calculated)	Assumes V channel, 2H:1V)	
14. Hydraulic radius, r=a/pw	0.64	ft		
Beginning Elevation	11200			
Ending Elevation	8700			
15. Channel slope, s	0.24			
16. Mannings RC, n	0.05			
17. V=1.49[(r^2/3)s^.5]/n	10.74	ft/s		
18. Flow Length	10500	ft		
19. Tt= L/3600V	0.27	hr	16.3 min	

D. Subarea Tc

20. Tt	0.68	hr	41.1 min

E. Basin Statistics

Elevation Drop:	3371 ft
Horizontal Flow Length:	11800 ft

file SH1-1

Summary of Results

Job:	101.9502
Project:	Rico
By:	ACJ
Location:	Silver Swan
Basin:	A8

Regional Regression Analyses

Basin Area:	76 acres	0.12 sq. mi.
Q:	22.7 cfs	

TR-55 Method

Q:	28.0 cfs

Rational Method

Q:	36.5 cfs

GRAPHICAL PEAK DISCHARGE METHOD   Version 2.00

Project : Rico Technical Services   User: ACJ   Date: 07-31-95
County : Dolores   State: CO   Checked: ___   Date: _______
Subtitle: Basin A8

Data: Drainage Area : 76 Acres
Runoff Curve Number : 58
Time of Concentration: 0.37 Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1
Frequency (yrs)	100
24-Hr Rainfall (in)	3.75
Ia/P Ratio	0.39
Runoff (in)	0.56
Unit Peak Discharge (cfs/acre/in)	0.664
Pond and Swamp Factor 0.0% Ponds Used	1.00
Peak Discharge (cfs)	28

Time of Concentration by TR-55 Methodology

Job: 101.9502
Project: Rico
By: ACJ
Location: Silver Swan
Basin: A8

Storm analyzed: 100 yr 6 hr

A. Sheet Flow

1. Surface description	Woods			
2. Manning's RC (n)	0.4			
3. Flow length, L	150	ft (MAX IS 300)		
4. rainfall	3.8	in	Suggested:	3.8 in
Beginning Elevation	10700			
Ending Elevation	10640			
5. Land slope, s	0.40	ft/ft		
6. Tt = 0.007(nl)^.8/(p2^.5*s^.4)	0.137	hr	8.2 min	

B. Shallow Concentrated Flow

7. Surface description	Unpaved		
8. Flow length, L	400	ft	
Beginning Elevation	10640		
Ending Elevation	10450		
9. Watercourse slope, s	0.48	ft/ft	
10. Average Velocity, V	2.3	ft/s	
11. Tt= L/(3600V)	0.048	hr	2.9 min

C. Channel Flow

Q (base flow from u/s subarea)	0			
Q (calculated - guess on first iteration)	7	(use about 1/4 of calculated Q at end of channel):		9.0 cfs
Q (total)	7			
Q (adjust flow area so to match this Q to abo	6.9			
12. Cross section flow area, a	0.9	ft2		
13. Wetted perimeter, pw	3.0	ft (calculated)	Assumes V channel, 2H:1V)	
14. Hydraulic radius, r=a/pw	0.30	ft		
Beginning Elevation	10450			
Ending Elevation	8700			
15. Channel slope, s	0.34			
16. Mannings RC, n	0.05			
17. V=1.49[(r^2/3)s^.5]/n	7.72	ft/s		
18. Flow Length	5200	ft		
19. Tt= L/3600V	0.19	hr	11.2 min	

D. Subarea Tc

20. Tt	0.37	hr	22.4 min

E. Basin Statistics

Elevation Drop:	2000 ft
Horizontal Flow Length:	5750 ft

file SH1-1

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Job:	101.9502
Project:	Rico Technical Services
By:	ACJ
Re:	Design Q, 100 yr, 6 hour design storm
Location:	Columbia Tailings
Basin:	~~A10 (Spear Slide)~~ A8

Inputs

Storm Recurrence Interval	100	yrs
Runoff Coefficient (C)	0.10	
Basin Area:	76	acres
Maximum Length of water travel:	5750	ft
TR-55 calculated time of concentration:	21.6	min
Time of concentration factor:	2.0	(for use in adjusting Kirpich formula)

Rainfall Intensity-Duration Curve

Duration (D, hrs)	(min)	I(in/hr)	dI/dD
0.083	5	6.75	-17.76
0.167	10	5.27	-9.96
0.250	15	4.44	-5.44
0.500	30	3.08	-2.26
1.000	60	1.95	-2.26

Work Area

Antecedent Precipitation Factors

Recurrence Interval (yrs)	Ca		
2	1	Ikey	0.25
10	1	Ibase	4.44
25	1.1	Idelta	-5.44
50	1.2		
100	1.25		

Results

Height drop of water travel:	2000	ft			
Antecedent Precipitation Factor (Ca)	1.25				
C * Ca	0.13				
Basin Slope:	34.8%				
Time of Concentration (Tc):	0.31	hrs	18.4	min	(Kirpich formula)
Tc for analysis:	0.36	hrs	21.6	min	(max of Kirpich or TR-55)
Average Water Velocity:	5.2	ft/s			
Intensity (I)	3.8	in/hr			
Q (=CCaIA)	36.5	cfs			

Time of Concentration by TR-55 Methodology

Job: 101.9502
Project: Rico
By: ACJ
Location: Silver Swan
Basin: A8

Storm analyzed: 100 yr 6 hr

A. Sheet Flow

1. Surface description	Woods			
2. Manning's RC (n)	0.4			
3. Flow length, L	150	ft (MAX IS 300)		
4. rainfall	3.8	in	Suggested:	3.8 in
Beginning Elevation	10700			
Ending Elevation	10640			
5. Land slope, s	0.40	ft/ft		
6. Tt = 0.007(nl)^.8/(p2^.5*s^.4)	0.137	hr	8.2 min	

B. Shallow Concentrated Flow

7. Surface description	Unpaved		
8. Flow length, L	400	ft	
Beginning Elevation	10640		
Ending Elevation	10450		
9. Watercourse slope, s	0.48	ft/ft	
10. Average Velocity, V	2.3	ft/s	
11. Tt= L/(3600V)	0.048	hr	2.9 min

C. Channel Flow

Q (base flow from u/s subarea)	0			
Q (calculated - guess on first iteration)	9.1	(use about 1/4 of calculated Q at end of channel):		9.1 cfs
Q (total)	9.1			
Q (adjust flow area so to match this Q to a	9.1			
12. Cross section flow area, a	1.1	ft2		
13. Wetted perimeter, pw	3.3	ft (calculated)	Assumes V channel, 2H:1V)	
14. Hydraulic radius, r=a/pw	0.33	ft		
Beginning Elevation	10450			
Ending Elevation	8700			
15. Channel slope, s	0.34			
16. Mannings RC, n	0.05			
17. V=1.49[(r^2/3)s^.5]/n	8.25	ft/s		
18. Flow Length	5200	ft		
19. Tt= L/3600V	0.18	hr	10.5 min	

D. Subarea Tc

20. Tt	0.36	hr	21.6 min

E. Basin Statistics

Elevation Drop:	2000	ft
Horizontal Flow Length:	5750	ft

file SH1-1

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Summary of Results

Job: 101.9502
Project: Rico
By: ACJ
Location: Silver Swan
Basin: Pile runoff

Regional Regression Analyses

Basin Area:	1.3 acres	0.00 sq. mi.
Q:	1.3 cfs	

Rational Method

Q:	3.3 cfs

Job:	101.9502
Project:	Rico Technical Services
By:	ACJ

Re:	Design Q, 100 yr, 6 hour design storm	
Location:	Silver Swan	0
Basin:	Pile runoff	

Inputs

Storm Recurrence Interval	100	yrs
Runoff Coefficient (C)	0.50	
Basin Area:	1.3	acres
Maximum Length of water travel:	315	ft
TR-55 calculated time of concentration:	18.6	min
Time of concentration factor:	2.0	(for use in adjusting Kirpich formula)

Rainfall Intensity-Duration Curve

Duration (D, hrs)	(min)	I(in/hr)	dI/dD
0.083	5	6.75	-17.76
0.167	10	5.27	-9.96
0.250	15	4.44	-5.44
0.500	30	3.08	-2.26
1.000	60	1.95	-2.26

Work Area

Antecedent Precipitation Factors

Recurrence Interval (yrs)	Ca		
		Ikey	0.25
		Ibase	4.44
2	1	Idelta	-5.44
10	1		
25	1.1		
50	1.2		
100	1.25		

Results

Height drop of water travel:	9	ft			
Antecedent Precipitation Factor (Ca)	1.25				
C * Ca	0.63				
Basin Slope:	2.9%				
Time of Concentration (Tc):	0.09	hrs	5.1	min	(Kirpich formula)
Tc for analysis:	0.31	hrs	18.6	min	(max of Kirpich or TR-55)
Average Water Velocity:	1.0	ft/s			
Intensity (I)	4.1	in/hr			
Q (=CCaIA)	3.3	cfs			

Time of Concentration by TR-55 Methodology

Job:	101.9502
Project:	Rico
By:	ACJ
Location:	Silver Swan
Basin:	Pile runoff

Storm analyzed: 100 yr 6 hr

A. Sheet Flow

1. Surface description	Grass			
2. Manning's RC (n)	0.24			
3. Flow length, L	150	ft (MAX IS 300)		
4. rainfall	4.1	in	Suggested:	4.1 in
Beginning Elevation	8700			
Ending Elevation	8697			
5. Land slope, s	0.0200	ft/ft		
6. Tt = 0.007(nl)^.8/(p2^.5*s^.4)	0.291	hr	17.4 min	

B. Shallow Concentrated Flow

7. Surface description	Unpaved		
8. Flow length, L	150	ft	
Beginning Elevation	8697		
Ending Elevation	8695		
9. Watercourse slope, s	0.01	ft/ft	
10. Average Velocity, V	2.3	ft/s	
11. Tt= L/(3600V)	0.018	hr	1.1 min

C. Channel Flow

Q (base flow from u/s subarea)	0		
Q (calculated - guess on first iteration)	0.8	(use about 1/4 of calculated Q at end of channel):	0.8 cfs
Q (total)	0.8		
Q (adjust flow area so to match this Q to abo	0.8		
12. Cross section flow area, a	0.2	ft2	
13. Wetted perimeter, pw	1.4	ft (calculated)	Assumes V channel, 2H:1V)
14. Hydraulic radius, r=a/pw	0.14	ft	
Beginning Elevation	8695		
Ending Elevation	8691		
15. Channel slope, s	0.27		
16. Mannings RC, n	0.05		
17. V=1.49[(r^2/3)s^.5]/n	4.15	ft/s	
18. Flow Length	15	ft	
19. Tt= L/3600V	0.00	hr	0.1 min

D. Subarea Tc

20. Tt	0.31	hr	18.6 min

E. Basin Statistics

Elevation Drop:	9 ft
Horizontal Flow Length:	315 ft

file SH1-1

C1B DOLORES RIVER HYDROLOGY

Attachment C1B-1
Validation of Hydrologic Reports

MEMORANDUM

TO: FILE

PROJECT: RICO SITE
ENVIRONMENTAL SUPPORT
SERVICES

FROM: GEA

JOB: 101-9502

DATE: 5/8/95

RE: VALIDATION OF HYDROLOGIC REPORTS AT THE RICO SITE

Review of Existing Hydrologic Studies

Overview

Two existing reports address the hydrology of the Dolores River Basin in the Rico area .

1.) Flood Hazard Areas Anaconda Mining Sites
Dolores River And Silver Creek
Rico, Colorado
Dames and Moore, January 1981

2.) Report on Environmental liability Assessment
of Rico-Argentine Mining Company
Rico, Colorado
Camp Dresser & McKee (CDM)
September 1979

FLOOD MAGNITUDE ANALYSIS OF THE DOLORES RIVER AND SILVER CREEK.

Dames and Moore:

The Dames and Moore report's objective was to determine the floods with recurrence intervals of 2, 10, 50, 100, 200, 500 intervals, the Standard Project Flood, and define the flood plain for the 100 year and SPF at the mine sites under existing conditions. Several methodologies were used to determine flood estimates within the range of frequencies listed above.

A.) Floods with Return Periods

1.) Frequency analysis: Annual maximum flows from the USGS gage below Rico (USGS No.09165000) were used to develop flood estimates with the specified recurrence intervals. At that point in time (1980) the gage had a data record of 29 years. Appropriate methodologies were used to assess the adequacy of the data set for statistical analyses. These included tests for: reliability, trends, shifts and independence. Analysis indicated the presence of one low outlier and data was correspondingly adjusted. A Log Pearson Type III distribution was used in the analysis. Peak flows from the frequency analysis were then adjusted according to the expected probability method. Results are shown in Table 1.

2.) Regional Regression Analysis: Regression equations developed from regional data by the Colorado Water Conservation Board associate annual flood peaks as a function of drainage basin area. This methodology was used both on the Dolores River and Silver Creek. Table 1 contains the results.

3.) Snowpack Water Equivalent Regression Analysis: A regression analysis was performed using snow water content on April 1 and annual flood peaks as parameters. Data records from three snow course sites in the Dolores river basin were utilized. Record lengths for the snow sites were 45 years, 36 years and 45 years. A frequency analysis was then conducted using a Log Pearson Type III distribution to determine snow-water contents for given return periods. The assumption was then made that the given water content and return period would produce a flood having the same return period. These water contents were then used in the regression equation correlating flows with snow water content. Results are listed in Table 1.

4.) Hec-1 Analysis: A Hec-1 analysis was conducted using the Degree - Day Method to generate a basin hydrograph from the snow melt runoff. Two simulations for two return periods were conducted. One used the water content with a 10 year and 100 year return period in conjunction with the mean temperature. The other simulation used the mean water content with temperatures having return periods of 10 years and 100 years. Hec-1 input files were not provided in the report therefore now review of input data was conducted. Results are listed in Table 1.

B.) Standard Project Flood: In order to estimate the SPF a Hec-1 analysis was conducted for the Dolores River and Silver Creek using the PMP to generate the PMF. The SPF was then taken as 50% of the PMF. While the snowmelt was identified as the mechanism for annual floods the PMF was based upon a rainfall induced event. The PMP was obtained from the "Army Corps of Engineers Hydrometeorlogical Report No. 49". Results are listed in Table 1

Camp Dresser & McKee

The CDM report's purpose was to determine necessary corrective measures needed to correct the former mining and manufacturing site in Rico. A portion of this study addressed peak flows with return periods for Silver Creek and the Dolores River.

A.) Floods with Return Periods

1.) Frequency Analysis: No apparent frequency analysis was conducted by CDM on the Rico gage data. CDM does provide a an exceedence curve (Figure 2) based upon flow records from the Dolores River below Rico gage. No reference/discussion is provided on the development or source of Figure 2. Data from Figure 2 is used in the regional regression analysis.

2.) Regional Regression Analysis: CDM used two regional regression methods to estimate peak flows for Silver Creek and the Dolores River. They confined their estimate to the flood with a 100 year return period. Both regional regression analyses relate peak flows with a specified return period to drainage basin area. One analysis was conducted by CDM the other by the State of Colorado Water Conservation Board. Limited information is provided on the development of the CDM analysis. Results are presented in Table 2.

Comments

The Dames and Moore report provides a rigorous peak flow analysis using several different methodologies. Certain assumptions used in the analyses have weaknesses (i.e. flood frequency equal to the snow-water content/temperature frequency). However the overall agreement between methods indicate estimates are reasonable.

The CDM peak flow analysis is not as robust or documented as well as the analysis conducted by Dames and Moore but yields similar results for the return periods examined. CDM's overall agreement with the Dames and Moore estimates provides additional confidence for the peak flow estimates.

Both reports identify the annual floods on the Dolores and Silver Creek as snow-melt induced. Report data from the USGS Dolores River Below Rico indicate annual maximum flows occur in the spring from May 3 through June 19. There is one annual maximum in the data record which occurred in the fall (9/6/70) of 1930 cfs indicating the event was most likely rain induced. CDM's report notes that regionally most annual floods are snow-melt induced during the spring but are smaller in magnitude than the infrequent floods during September and October which would be rain induced. This is also stated in the State of Colorado's Technical Manual No. 1 for the Southern Plateau Region. The SPF and the PMF would most likely be rain induced.

For floods on the Dolores River with return periods the frequency analysis conducted by Dames and Moore provides the best estimate because it is based upon actual data.
For floods on Silver Creek it is necessary to use estimates based upon the regional regression analysis. Considering the good agreement between the regional regression analysis and the frequency analysis for the Dolores River, the regional regression methodology should yield a reasonable peak flow estimate on Silver Creek.

Hec-2 Review

Dames and Moore conducted a Hec-2 analysis for the Dolores River and Silver Creek for the 100 year and the SPF events. Both subcritical and supercritical simulations were conducted. Input/output (I/O) data were reviewed in detail for the 100 year subcritical profile. The review considered:

- Output Error Statements
- Reach lengths and Cross Section Spacing
- Mannings n Values
- Expansion/Contraction Coefficients
- Bridge Routines
- Discharge Changes at Stream Junctions
- Supercritical Reaches

Lack of input data in an ASCII format somewhat limited the review.

Output for the subcritical profiles is generally free from any significant errors. Cross-section spacing appears adequate. Cross-sections are orientated looking upstream, opposite the standard downstream orientation. Overbank reach lengths are the same as the channel reach lengths in effect simulating a straight flood channel. This does not represent the actual system nor the cross-sections illustrated in Plates 7 through 13. Reach lengths should represent changes in direction of the mass flow path. Mannings n values appear reasonable but should be validated through photographs or a field visit. Expansion and contraction coefficients were not adjusted for bridge locations. The sensitivity of the profile simulation to these expansion contraction coefficients varies based upon the velocities. Usually changes in the expansion/contraction coefficients result in small changes in flood stage. Normal bridge routines were used throughout the profile simulation, including the culverts on Silver Creek (n values were changed through the culvert to represent coated metal). Output data indicates the bridge near the Santa Cruz mine would be overtopped during the 100 year flood as well as the culverts in Silver Creek. No discharge adjustment is made at the junction of Silver Creek and the Dolores, therefore profile calculations upstream of the Silver Creek/Dolores confluence represent the full magnitude of the 100 year flood (i.e. includes contribution from Silver Creek, a conservative simplification). Output data indicates supercritical flow in Silver Creek reach adjacent to the upper three ponds (this reach includes velocities of 40 fps during the 100 year flood). Output for the Dolores profile indicates a supercritical reach immediately downstream of the Route 145 bridge.

Comments

The profile analysis appears to yield reasonable results for existing conditions in 1979. The most significant weakness is in the representation of the overbank reach lengths which fails to account for changing flow path lengths in the overbank areas. As these reach lengths are used to calculate energy losses between cross-sections, this could effect computed water surface elevations. Recommended expansion/contraction coefficients should be utilized anywhere significant expansions or contractions exist.

For preliminary design the existing analyses should be adequate for final design refinements may be necessary.

Recommended Additional Work

Assuming the Dolores River USGS gage has been active since 1980, the additional data would increase the data record by almost 50% (14 years). Revaluating the frequency analysis would provide the best estimate for peak flows with return periods.

Any revisions/updates to the State of Colorado's regional regression analysis should be utilized to provide the best estimate for the Silver Creek peak flows with return frequencies.

If a design flood other than the 100 year or the SPF is chosen additional profile simulations will be required.

Changes/improvements in the Silver Creek channel and their affect on the profile and channel velocities should be investigated.

Any design features encroaching on the flood plain should be simulated.

Summary

Two reports containing hydrologic analyses were reviewed for adequacy. Both contained flood frequency analyses that were in good agreement utilizing several methodologies. Thus the flood frequency estimates are considered to be reasonable values based upon strong analyses. An updated flood frequency analysis is recommended based upon the additional record length of flow data on the Dolores River Rico gage. The Dames and Moore report also conducted a river profile analysis using the Hec-2 model. Profiles were calculated for the 100 year flood and the SPF on the Dolores river and Silver Creek. The simulations have some deficiencies but appear adequate for preliminary design work. Design flows other than the 100 year and the SPF and/or design features encroaching into the flood plain will require modification of the existing simulations.

05/12/95

TABLE 1
DOLORES RIVER PEAK FLOW SUMMARY

DAMES AND MOORE

RETURN PERIOD (YRS)	PEAK FLOWS FREQUENCY ANALYSIS: LP III PEAK FLOW (CFS)	PEAK FLOWS FREQUENCY ANALYSIS: EXPECTED PROBABILITY (CFS)	PEAK FLOWS REGIONAL REGRESSION ANALYSIS: AREA DEPENDENT (ST. OF COLO.) (CFS)	PEAK FLOWS REGIONAL REGRESSION ANALYSIS: WATER CONTENT DEPENDENT (CFS)	HEC-1 ANALYSIS: VARYING TEMPERATURE (CFS)	HEC-1 ANALYSIS: VARYING WATER CONTENT (CFS)	PMF (CFS)	SPF (CFS)
2	1249	1249	1280	1230				
10	1871	1920	1865	1752	1942	1837		
50	2395	2480	2390	2028				
100	2604	2720	2690	2120	3064	2014		
200	2810	2960	3100	2192				
500	3075	3400	3783	2275				
> 10000							15846	7900

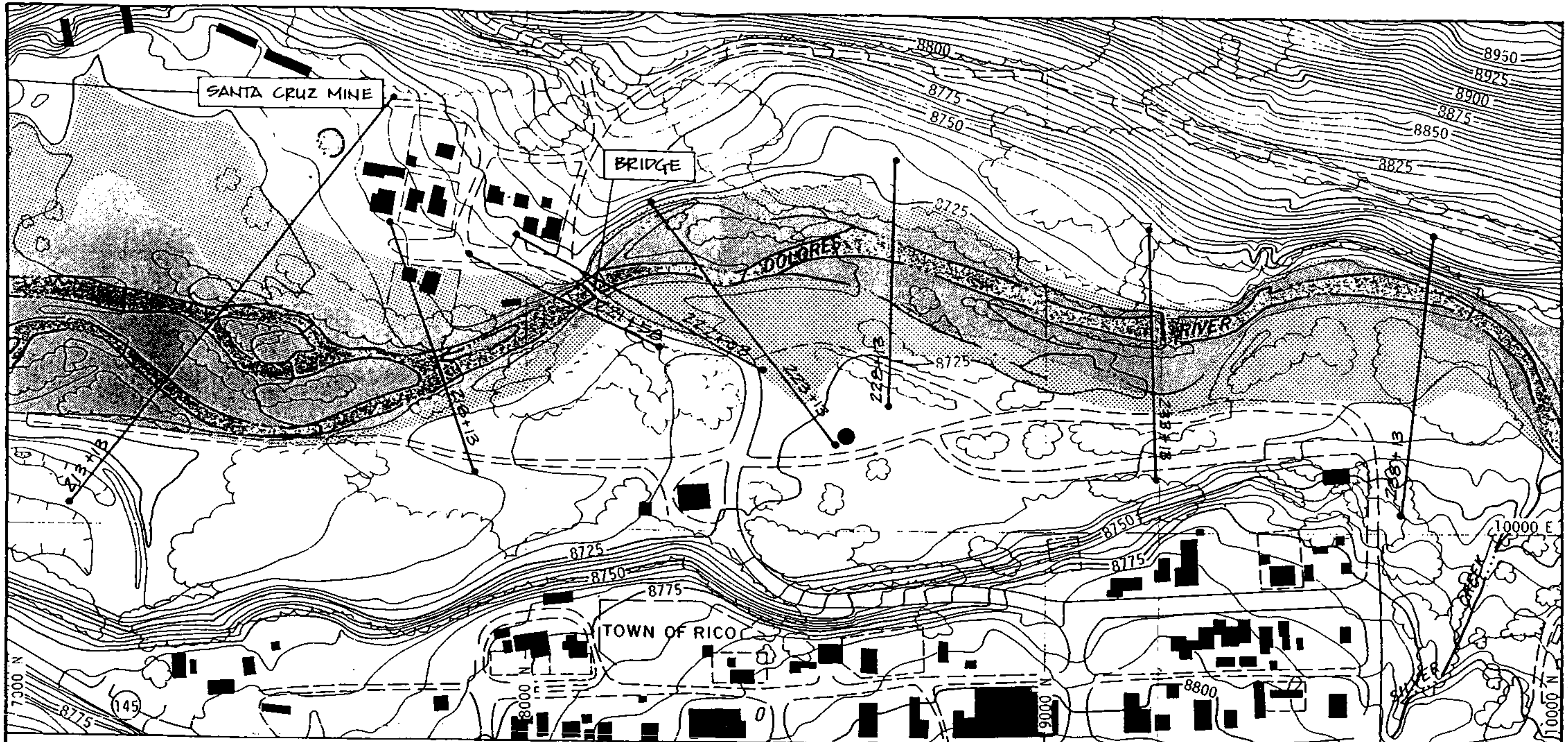
CAMP DRESSER AND McKEE

RETURN PERIOD (YRS)	PEAK FLOWS REGIONAL REGRESSION ANALYSIS AREA DEPENDENT: CDM (CFS)	PEAK FLOWS REGIONAL REGRESSION ANALYSIS AREA DEPENDENT: ST OF COLO (CFS)
2		
10		
50		
100	2700	2862
200		
500		

TABLE 2

SILVER CREEK PEAK FLOW SUMMARY

RETURN PERIOD	DAMES AND MOORE REGRESSION ANALYSIS	DAMES AND MOORE HEC-1		CAMP DRESSER AND McKEE PEAK FLOWS REGIONAL REGRESSION ANALYSIS	
	AREA DEPENDENT (ST. OF COLO.)	PMF	SPF	AREA DEPENDENT CDM	AREA DEPENDENT ST OF COLO
(YRS)	(CFS)	(CFS)	(CFS)	(CFS)	(CFS)
2	200				
10	305				
50	456				
100	528			530	494
200	600				
500	703				
> 10000		4000	2000		



(Dames & Moore, 1981)

NOTES

1. Horizontal and vertical datum based on Anaconda coordinate system
2. Limits of overflow may vary due to accuracy of topographic mapping

SCALE IN FEET

200 100 0 200 400

1" = 200'

CONTOUR INTERVAL = 5 FEET

MAP FROM INTRASEARCH TOPOGRAPHIC MAP
DATE: AUGUST 17, 1980

FLOODPLAIN LIMITS

LOW WATER CHANNEL — 100 YEAR FLOOD — STANDARD PROJECT FLOOD

145 STATE HIGHWAY

POND AREA

555+00 CROSS SECTION

INDEX MAP LOCATION

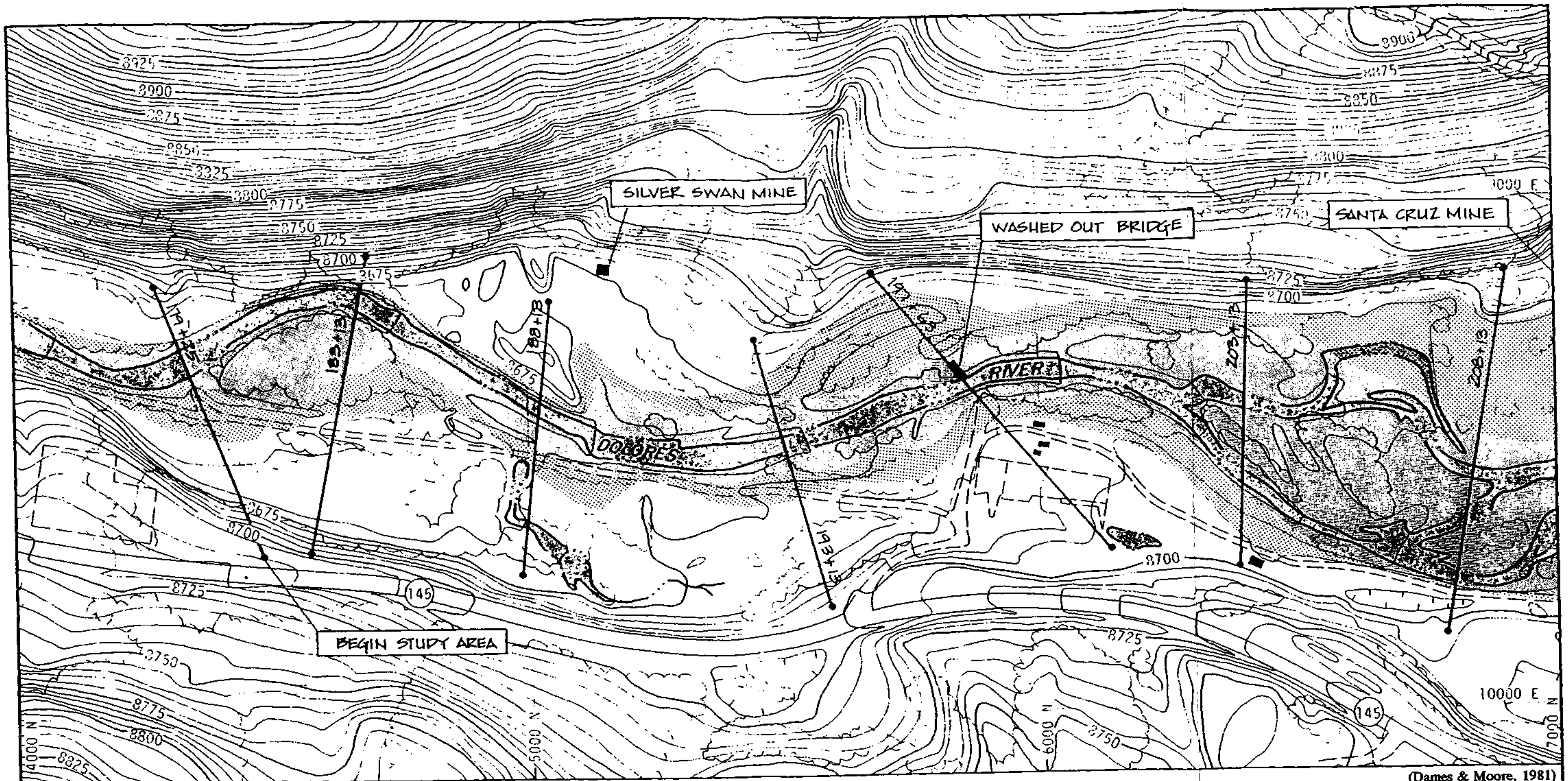
Z

FLOODED AREAS

DOLORES RIVER
RICO, COLORADO

DECEMBER, 1980

Dames & Moore



(Dames & Moore, 1981)

NOTES

1 Horizontal and vertical datum based on Anaconda coordinate system

2 Limits of overflow may vary due to accuracy of topographic mapping.

SCALE IN FEET

200 100 0 200 400

1" = 200'

CONTOUR INTERVAL = 5 FEET

MAP FROM INTRASEARCH TOPOGRAPHIC MAP
DATE AUGUST 17, 1980

FLOODPLAIN LIMITS

LOW WATER CHANNEL

100 YEAR FLOOD

STANDARD PROJECT FLOOD

145 STATE HIGHWAY

POND AREA

555+00 CROSS SECTION

INDEX MAP LOCATION

N

FLOODED AREAS

DOLORES RIVER
RICO, COLORADO

DECEMBER, 1980

Dames & Moore

Attachment C1B-2
Period Evaluation

ATSTORE PEAK FLOW FILE RETRIEVAL PGM. J980 - RUN DATE : 18 MAY 95 10.25.22
ROGRAM LAST REVISED : 3 OCT 83 18.25.23

** EXPLANATION OF PEAK DATA CODES *****

DISCHARGE QUALIFICATION CODES:

1...DISCHARGE IS A MAXIMUM DAILY AVERAGE
2...DISCHARGE IS AN ESTIMATE
3...DISCHARGE AFFECTED BY DAM FAILURE
4...DISCHARGE LESS THAN INDICATED VALUE, WHICH IS MINIMUM RECORDABLE DISCHARGE AT THIS SITE
5...DISCHARGE AFFECTED TO UNKNOWN DEGREE BY REGULATION OR DIVERSION
6...DISCHARGE AFFECTED BY REGULATION OR DIVERSION
7...DISCHARGE IS AN HISTORIC PEAK
8...DISCHARGE ACTUALLY GREATER THAN INDICATED VALUE
9...DISCHARGE DUE TO SNOWMELT, HURRICANE, ICE-JAM OR DEBRIS DAM BREAKUP
A...YEAR OF OCCURRENCE IS UNKNOWN OR NOT EXACT
B...MONTH OR DAY OF OCCURRENCE IS UNKNOWN OR NOT EXACT
C...ALL OR PART OF THE RECORD AFFECTED BY URBANIZATION, MINING, AGRICULTURAL CHANGES, CHANNELIZATION, OR OTHER
D...BASE DISCHARGE CHANGED DURING THIS YEAR
E...ONLY ANNUAL MAXIMUM PEAK AVAILABLE FOR THIS YEAR

GAGE HEIGHT QUALIFICATION CODES:

1...GAGE HEIGHT AFFECTED BY BACKWATER
2...GAGE HEIGHT NOT THE MAXIMUM FOR THE YEAR
3...GAGE HEIGHT AT DIFFERENT SITE AND/OR DATUM
4...GAGE HEIGHT BELOW MINIMUM RECORDABLE ELEVATION
5...GAGE HEIGHT IS AN ESTIMATE
6...GAGE DATUM CHANGED DURING THIS YEAR

** NOTES *****

ASE DISCHARGE (IF REPORTED) MAY NOT BE EFFECTIVE FOR ENTIRE PERIOD OF RECORD; CURRENT VALUE USED.

AGE DATUM (IF REPORTED) MAY NOT BE EFFECTIVE FOR ENTIRE PERIOD OF RECORD; CURRENT VALUE USED.

ETRIEVAL SPECIFICATIONS FOR REQUEST NUMBER 01 ARE AS FOLLOWS:
CARD: M 195110 198009 01
EAK FLOW RETRIEVAL NUMBER 01 IS FOR WATER YEARS 1952 THROUGH 1980
HE FOLLOWING HAVE BEEN REQUESTED:
....LONG FORMAT PRINTOUT
....STANDARD RECORD FORMAT

....VECTOR FORMAT(FROM X CARD) --XJ407 $JOB-FOR GEORGE AUSTIGUY

UMBER OF SITES RETRIEVED: 1
UMBER OF RECORDS RETRIEVED: 29

ND OF RETRIEVAL PROCESSING

STATION 09165000 DOLORES RIVER BELOW RICO, CO.

AGENCY: USGS	STATION LOCATOR	DRAINAGE AREA:	105.00	SQ MI
STATE: 08	LAT. LONG.	CONTRIBUTING		
COUNTY: 033		DRAINAGE AREA:		SQ MI

DISTRICT: 08 373820 1080335 GAGE DATUM: 8422.23 (NGVD)
BASE DISCHARGE: 800.00 CFS

WATER YEAR	DATE	PEAK DISCHARGE (CFS)	DISCHARGE CODES	GAGE HEIGHT (FT)	GAGE HT CODES	HIGHEST SINCE	MAX GAGE HEIGHT (FT)	DATE	GAGE HT CODES	NUMBER OF PARTIAL PEAKS
1952	06/10/52	2120.00		6.15						3
	05/05/52	1190.00		5.20						
	05/14/52	1370.00		5.43						
	07/06/52	1030.00		4.68						
1953	05/28/53	1460.00		5.30						2
	06/03/53	1030.00		4.69						
	06/12/53	1170.00		4.89						
1954	05/21/54	786.00		4.30						0
1955	06/08/55	1360.00		5.15						0
1956	05/31/56	1020.00		4.65						0
1957	06/05/57	2080.00		6.07						2
	06/27/57	2000.00		5.77						
	07/26/57	1520.00		5.38						
1958	05/27/58	1900.00		5.60	2		5.75	06/05/58		2
	05/11/58	1050.00		4.81						
	06/05/58	1860.00		5.75						
1959	05/15/59	585.00		4.15						0
1960	06/03/60	1170.00		5.05						3
	05/12/60	1060.00		4.90						
	05/22/60	833.00		4.57						
	06/16/60	938.00		4.78						
1961	05/19/61	1020.00		4.85						1
	06/02/61	994.00		4.81						
1962	05/09/62	1190.00		5.05						1
	06/13/62	860.00		4.60						
1963	05/08/63	867.00		4.58						1
	05/16/63	811.00		4.49						
1964	05/26/64	1220.00		5.09						2
	05/17/64	1180.00		5.01						
	06/06/64	902.00		4.66						
1965	05/21/65	1330.00		5.17						5
	05/02/65	909.00		4.61						
	06/07/65	1080.00		4.91						
	06/20/65	1300.00		5.14						
	07/02/65	1050.00		4.77						
	07/12/65	1060.00		4.73						
1966	05/09/66	951.00		4.60						1
	05/23/66	874.00		4.52						
1967	05/21/67	769.00		4.40						0
1968	06/04/68	1360.00		5.00						2
	05/22/68	930.00		4.60						
	06/16/68	1200.00								
1969	05/30/69	1210.00		4.76						2
	05/23/69	1000.00		4.60						
	06/09/69	811.00		4.23						
1970	09/06/70	1930.00		5.88						1
	05/17/70	1420.00		5.08						
1971	06/17/71	1100.00		4.66						0
1972	06/08/72	776.00		4.43						0
1973	06/11/73	1810.00		5.69						1
	05/19/73	1420.00		5.23						
1974	05/10/74	783.00		4.41						0
1975	06/05/75	1620.00		5.43						1
	06/15/75	1600.00		5.38						
1976	06/04/76	958.00		4.73						1
	05/17/76	909.00		4.62						
1977	[illegible]5/09/77	270.00		3.41						0

1978	06/10/78	1330.00	5.12	0
1979	06/13/79	1600.00	5.36	2
	05/29/79	1380.00	5.20	
	06/06/79	1560.00	5.36	
1980	06/10/80	1770.00	5.57	1
	05/23/80	1050.00	4.74	

ND OF PROGRAM J980.

GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING WRC GUIDELINES BULL. 17-B.

XECUTION BEGINNING AT DATE, TIME = 5/18/95 1025

NPUT FORMAT = 1 WATSTORE PEAK FILE RETRIEVAL

EXPLANATION OF PEAK DISCHARGE QUALIFICATION CODES

J407 FILE MEANING

```
  D       3    DAM FAILURE, NON-RECURRENT FLOW ANOMALY
  G       8    DISCHARGE GREATER THAN STATED VALUE
  X      3+8   BOTH OF THE ABOVE
  L       4    DISCHARGE LESS THAN STATED VALUE
  K     6 OR C KNOWN EFFECT OF REGULATION OR URBANIZATION
  H       7    HISTORIC PEAK


EPORT TROUBLE TO WATSTORE USER ASSISTANCE.





       J407 -- REVISED FOR USE WITH W.R.C. BULLETIN 17-B.   8/1/81

    PEAK FLOW FILE RETRIEVAL VERSION

    PRINCIPAL CHANGES INCLUDE --
    -- HIGH OUTLIER TEST
    -- MORE SENSITIVE LOW OUTLIER TEST
    -- STATION SKEW ADJUSTMENT FOR LOW OUTLIERS AND ZERO FLOWS
    -- WEIGHTED AVERAGING OF STATION AND GENERALIZED SKEWS IN
         INVERSE PROPORTION TO ESTIMATED MEAN SQUARE ERRORS.

    FOR DETAILS, SEE WATSTORE USER'S GUIDE, VOL.4, CH.I (1981
    REVISION), SEC.C.

    NO CHANGES IN JOB INPUT PREPARATION ARE REQUIRED IN RETRIEVAL MODE
    MINOR CHANGES MAY BE REQUIRED IN STANDALONE (CARD INPUT) MODE.

 NOTE -- IN STANDALONE MODE (CARD INPUT), A NEW FORMAT IS USED FOR
    HISTORIC AND OUTLIER INFORMATION.  SEE WATSTORE USER'S GUIDE,
    VOL.4, CH.I, SEC.C.2.K (1981 REVISION).  NO CHANGE IS NEEDED
    FOR STATIONS HAVING NO HISTORIC/OUTLIER INFORMATION.

 NOTE -- IN STANDALONE MODE, USE REGION=140K ON THE EXEC CARD.


NOTE --  SUMMARY OUTPUT IS PRODUCED BY DEFAULT, UNLESS SUPPRESSED BY
    THE  NOBC  OPTION.  (BCPU IS THE DEFAULT OPTION.)  BCPU OUTPUT

    ORDINARILY GOES TO A TEMPORARY DATA SET NAMED &&BCCARDS, WHICH IS
    AVAILABLE TO LATER STEPS OF THE JOB IN WHICH IT WAS CREATED, BUT
    IS DELETED AT THE END OF THE JOB.  TO GET A PERMANENT ONLINE DATA
    SET, TYPE BCU=ONLINE,BCDS='USERID.DATA.SET.NAME'  ON THE EXEC
    CARD FOR PKWRCA.  TO GET ACTUAL PUNCHED CARDS, TYPE BCOUT=SYSOUT
    INSTEAD.  SEE WATSTORE USER'S GUIDE VOL.4, CH.I, SEC. C.2.G & H.


 NOTE -- OLD J407 PROGRAM IS STILL AVAILABLE FOR TESTS AND COMPARISONS
    TO USE IT, TYPE PROG=J407A ON THE EXEC CARD.



GM J407 VER 3.7                              U. S. GEOLOGICAL SURVEY
REV  11/5/81)                        ANNUAL  PEAK  FLOW  FREQUENCY  ANALYSIS        -FOR GEORGE AUSTIGUY
                                      FOLLOWING WRC GUIDELINES BULL. 17-B.           RUN-DATE  5/18/95 AT 1025   SEQ  1.0001

OPTIONS IN EFFECT --   PLOT  BCPU  LGPT  NODB  PPOS  NORS  EXPR  CLIM

 STATION - [illegible]5000     /USGS    DOLORES RIVER BELOW RICO, CO.           [illegible]952-1980               09165000      /USGS
```

I N P U T   D A T A   S U M M A R Y

-- YEARS OF RECORD -- SYSTEMATIC	HISTORIC	HISTORIC PEAKS	GENERALIZED SKEW	STD. ERROR OF GENERAL. SKEW	SKEW OPTION	GAGE BASE DISCHARGE	USER-SET OUTLIER CRITERIA HIGH OUTLIER	LOW OUTLIER
29	0	0	-0.114	--	WRC WEIGHTED	0.0	--	--

********* NOTICE -- PRELIMINARY MACHINE COMPUTATIONS. *********
********* USER RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION. *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE. 0.0
WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED. 1 378.9
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE. 2907.7

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE DISCHARGE	FLOOD BASE EXCEEDANCE PROBABILITY	LOGARITHMIC MEAN	LOGARITHMIC STANDARD DEVIATION	LOGARITHMIC SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.0634	0.1902	-1.255
W R C ESTIMATE	378.9	0.9655	3.0783	0.1535	-0.166

ANNUAL FREQUENCY CURVE ORDINATES -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	W R C ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR W R C ESTIMATES LOWER	UPPER
0.9950	--	228.2	--	--	--
0.9900	--	287.0	--	--	--
0.9500	658.7	499.5	636.8	535.3	762.7
0.9000	756.8	643.5	737.9	634.3	861.8
0.8000	892.1	842.3	881.1	771.8	1000.9
0.5000	1209.2	1265.2	1209.2	1083.0	1351.5
0.2000	1616.4	1672.6	1634.5	1440.3	1870.2
0.1000	1871.0	1852.5	1911.6	1645.2	2226.5
0.0400	2178.0	2008.9	2253.6	1880.8	2680.1
0.0200	2397.3	2089.4	2517.8	2043.6	3017.6
0.0100	2609.5	2148.4	2772.4	2197.8	3353.6
0.0050	2816.8	2192.2	3041.7	2345.6	3689.7
0.0020	3085.4	2233.6	3398.9	2533.6	4136.4

GM J407 VER 3.7
REV 11/5/81)
U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING WRC GUIDELINES BULL. 17-B.
-FOR GEORGE AUSTIGUY
RUN-DATE 5/18/95 AT 1025 SEQ 1.0001

STATION - 09165000 /USGS DOLORES RIVER BELOW RICO, CO. 1952-1980 09165000 /USGS

********* NOTICE -- PRELIMINARY MACHINE COMPUTATIONS. *********
********* USER RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION. *********

INPUT DATA LISTING

WATER YEAR	DISCHARGE	CODES
1952	2120.0	
1953	1460.0	

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

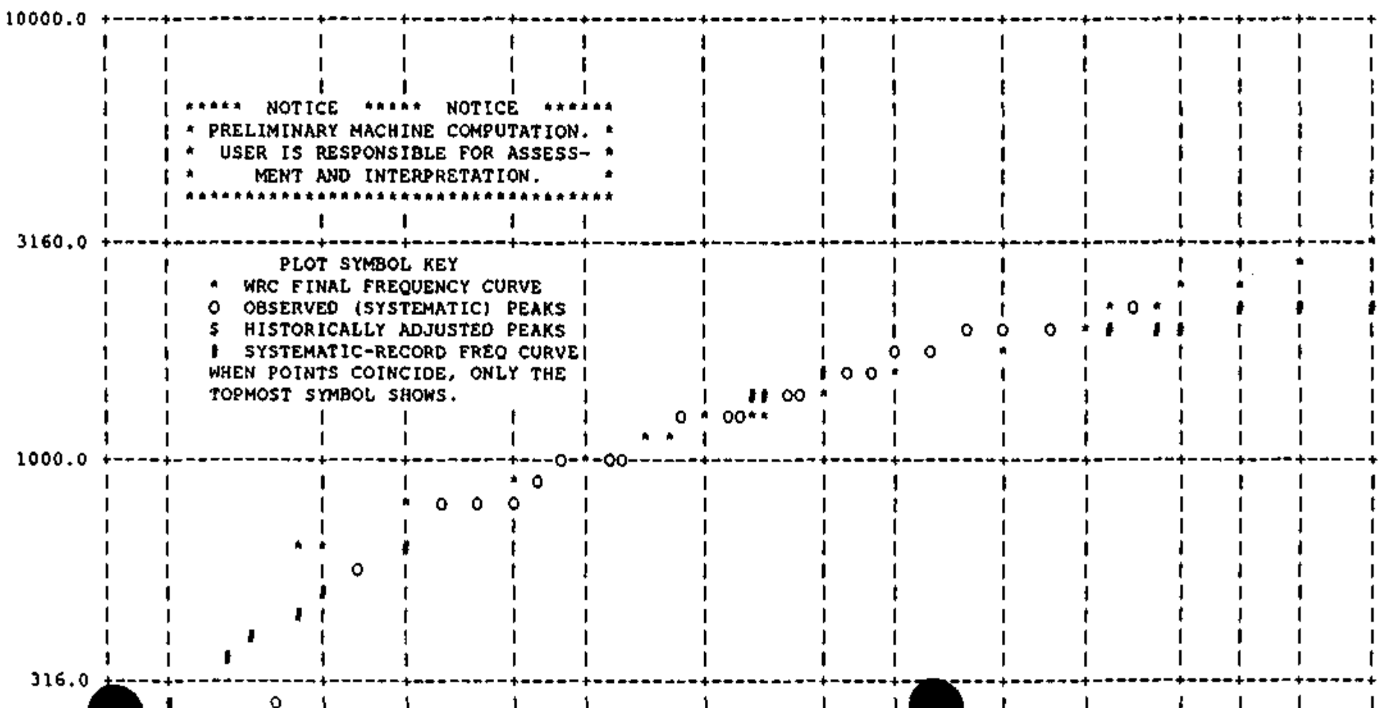
WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	W R C ESTIMATE
1952	2120.0	0.0333	0.0333
1957	2080.0	0.0667	0.0667

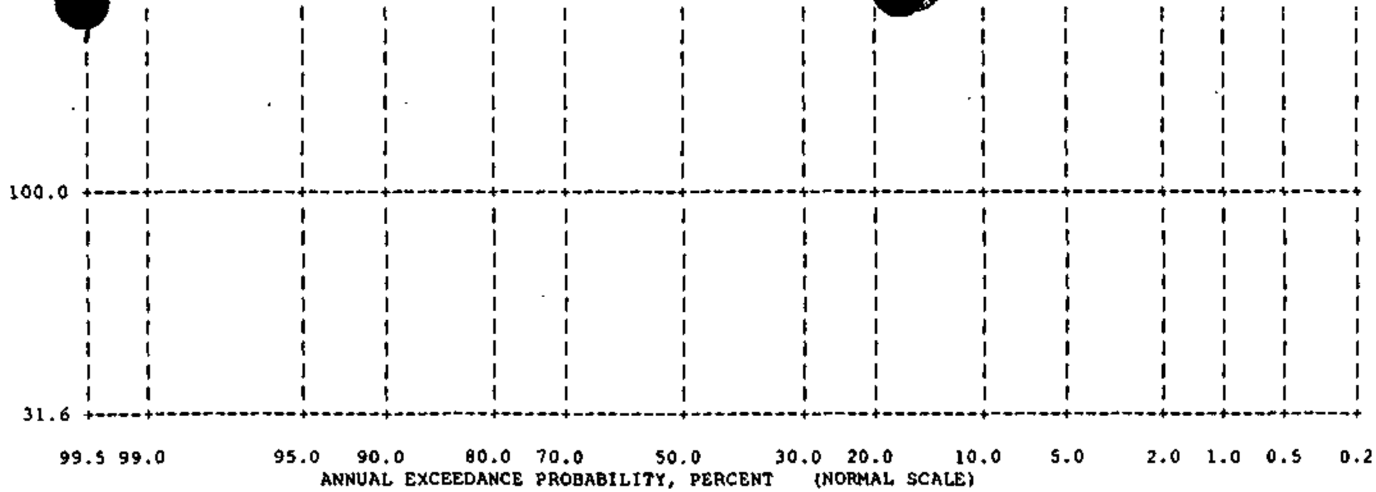
1954	786.0	1970	1930.0	0.1000	0.1000
1955	1360.0	1958	1900.0	0.1333	0.1333
1956	1020.0	1973	1810.0	0.1667	0.1667
1957	2080.0	1980	1770.0	0.2000	0.2000
1958	1900.0	1975	1620.0	0.2333	0.2333
1959	585.0	1979	1600.0	0.2667	0.2667
1960	1170.0	1953	1460.0	0.3000	0.3000
1961	1020.0	1955	1360.0	0.3333	0.3333
1962	1190.0	1968	1360.0	0.3667	0.3667
1963	867.0	1965	1330.0	0.4000	0.4000
1964	1220.0	1978	1330.0	0.4333	0.4333
1965	1330.0	1964	1220.0	0.4667	0.4667
1966	951.0	1969	1210.0	0.5000	0.5000
1967	769.0	1962	1190.0	0.5333	0.5333
1968	1360.0	1960	1170.0	0.5667	0.5667
1969	1210.0	1971	1100.0	0.6000	0.6000
1970	1930.0	1956	1020.0	0.6333	0.6333
1971	1100.0	1961	1020.0	0.6667	0.6667
1972	776.0	1976	958.0	0.7000	0.7000
1973	1810.0	1966	951.0	0.7333	0.7333
1974	783.0	1963	867.0	0.7667	0.7667
1975	1620.0	1954	786.0	0.8000	0.8000
1976	958.0	1974	783.0	0.8333	0.8333
1977	270.0	1972	776.0	0.8667	0.8667
1978	1330.0	1967	769.0	0.9000	0.9000
1979	1600.0	1959	585.0	0.9333	0.9333
1980	1770.0	1977	270.0	0.9667	0.9667

GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS -FOR GEORGE AUSTIGUY
FOLLOWING WRC GUIDELINES BULL. 17-B. RUN-DATE 5/18/95 AT 1025 SEQ 1.0001

STATION - 09165000 /USGS DOLORES RIVER BELOW RICO, CO. 1952-1980 09165000 /USGS





GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING WRC GUIDELINES BULL. 17-B.

-FOR GEORGE AUSTIGUY
RUN-DATE 5/18/95 AT 1025 SEQ 1.0002

ATSTORE PEAK FLOW FILE RETRIEVAL PGM. J980 - RUN DATE : 18 MAY 95 10.30.14
ROGRAM LAST REVISED : 3 OCT 83 18.25.23

** EXPLANATION OF PEAK DATA CODES *****

DISCHARGE QUALIFICATION CODES:

1...DISCHARGE IS A MAXIMUM DAILY AVERAGE
2...DISCHARGE IS AN ESTIMATE
3...DISCHARGE AFFECTED BY DAM FAILURE
4...DISCHARGE LESS THAN INDICATED VALUE, WHICH IS MINIMUM RECORDABLE DISCHARGE AT THIS SITE
5...DISCHARGE AFFECTED TO UNKNOWN DEGREE BY REGULATION OR DIVERSION
6...DISCHARGE AFFECTED BY REGULATION OR DIVERSION
7...DISCHARGE IS AN HISTORIC PEAK
8...DISCHARGE ACTUALLY GREATER THAN INDICATED VALUE
9...DISCHARGE DUE TO SNOWMELT, HURRICANE, ICE-JAM OR DEBRIS DAM BREAKUP
A...YEAR OF OCCURRENCE IS UNKNOWN OR NOT EXACT
B...MONTH OR DAY OF OCCURRENCE IS UNKNOWN OR NOT EXACT
C...ALL OR PART OF THE RECORD AFFECTED BY URBANIZATION, MINING, AGRICULTURAL CHANGES, CHANNELIZATION, OR OTHER
D...BASE DISCHARGE CHANGED DURING THIS YEAR
E...ONLY ANNUAL MAXIMUM PEAK AVAILABLE FOR THIS YEAR

GAGE HEIGHT QUALIFICATION CODES:

1...GAGE HEIGHT AFFECTED BY BACKWATER
2...GAGE HEIGHT NOT THE MAXIMUM FOR THE YEAR
3...GAGE HEIGHT AT DIFFERENT SITE AND/OR DATUM
4...GAGE HEIGHT BELOW MINIMUM RECORDABLE ELEVATION
5...GAGE HEIGHT IS AN ESTIMATE
6...GAGE DATUM CHANGED DURING THIS YEAR

** NOTES *****

ASE DISCHARGE (IF REPORTED) MAY NOT BE EFFECTIVE FOR ENTIRE PERIOD OF RECORD; CURRENT VALUE USED.

AGE DATUM (IF REPORTED) MAY NOT BE EFFECTIVE FOR ENTIRE PERIOD OF RECORD; CURRENT VALUE USED.

ETRIEVAL SPECIFICATIONS FOR REQUEST NUMBER 01 ARE AS FOLLOWS:
CARD: M   199409   01
EAK FLOW RETRIEVAL NUMBER 01 IS FOR ALL YEARS THROUGH 1994
HE FOLLOWING HAVE BEEN REQUESTED:
....LONG FORMAT PRINTOUT
....STANDARD RECORD FORMAT

....VECTOR FORMAT(FROM X CARD) --XJ407 $JOB-FOR GEORGE AUSTIGUY

UMBER OF SITES RETRIEVED: 1
UMBER OF RECORDS RETRIEVED: 43

ND OF RETRIEVAL PROCESSING

STATION 09165000   DOLORES RIVER BELOW RICO, CO.

AGENCY:	USGS	STATION LOCATOR	DRAINAGE AREA:	105.00 SQ MI
STATE:	08	LAT. LONG.	CONTRIBUTING	
COUNTY:	033		DRAINAGE AREA:	SQ MI

DISTRICT: 08 373820 1080335 GAGE DATUM: 8422.23 (NGVD)
BASE DISCHARGE: 800.00 CFS

WATER YEAR	DATE	PEAK DISCHARGE (CFS)	DISCHARGE CODES	GAGE HEIGHT (FT)	GAGE HT CODES	HIGHEST SINCE	MAX GAGE HEIGHT (FT)	DATE	GAGE HT CODES	NUMBER OF PARTIAL PEAKS
1952	06/10/52	2120.00		6.15						3
	05/05/52	1190.00		5.20						
	05/14/52	1370.00		5.43						
	07/06/52	1030.00		4.68						
1953	05/28/53	1460.00		5.30						2
	06/03/53	1030.00		4.69						
	06/12/53	1170.00		4.89						
1954	05/21/54	786.00		4.30						0
1955	06/08/55	1360.00		5.15						0
1956	05/31/56	1020.00		4.65						0
1957	06/05/57	2080.00		6.07						2
	06/27/57	2000.00		5.77						
	07/26/57	1520.00		5.38						
1958	05/27/58	1900.00		5.60	2		5.75	06/05/58		2
	05/11/58	1050.00		4.81						
	06/05/58	1860.00		5.75						
1959	05/15/59	585.00		4.15						0
1960	06/03/60	1170.00		5.05						3
	05/12/60	1060.00		4.90						
	05/22/60	833.00		4.57						
	06/16/60	938.00		4.78						
1961	05/19/61	1020.00		4.85						1
	06/02/61	994.00		4.81						
1962	05/09/62	1190.00		5.05						1
	06/13/62	860.00		4.60						
1963	05/08/63	867.00		4.58						1
	05/16/63	811.00		4.49						
1964	05/26/64	1220.00		5.09						2
	05/17/64	1180.00		5.01						
	06/06/64	902.00		4.66						
1965	05/21/65	1330.00		5.17						5
	05/02/65	909.00		4.61						
	06/07/65	1080.00		4.91						
	06/20/65	1300.00		5.14						
	07/02/65	1050.00		4.77						
	07/12/65	1060.00		4.73						
1966	05/09/66	951.00		4.60						1
	05/23/66	874.00		4.52						
1967	05/21/67	769.00		4.40						0
1968	06/04/68	1360.00		5.00						2
	05/22/68	930.00		4.60						
	06/16/68	1200.00								
1969	05/30/69	1210.00		4.76						2
	05/23/69	1000.00		4.60						
	06/09/69	811.00		4.23						
1970	09/06/70	1930.00		5.88						1
	05/17/70	1420.00		5.08						
1971	06/17/71	1100.00		4.66						0
1972	06/08/72	776.00		4.43						0
1973	06/11/73	1810.00		5.69						1
	05/19/73	1420.00		5.23						
1974	05/10/74	783.00		4.41						0
1975	06/05/75	1620.00		5.43						1
	06/15/75	1600.00		5.38						
1976	06/04/76	958.00		4.73						1
	05/17/76	909.00		4.62						
1977	05/09/77	270.00		3.41						0

1978	06/10/78	1330.00	5.12	0
1979	06/13/79	1600.00	5.36	2
	05/29/79	1380.00	5.20	
	06/06/79	1560.00	5.36	
1980	06/10/80	1770.00	5.57	1
	05/23/80	1050.00	4.74	
1981	06/07/81	878.00	4.37	0
1982	08/25/82	1610.00	5.19	1
	05/29/82	1080.00	4.78	
1983	06/19/83	1590.00	5.40	1
	05/30/83	1550.00	5.34	
1984	05/24/84	2170.00	5.95	3
	05/15/84	1260.00	5.08	
	06/13/84	1000.00	4.78	
	06/25/84	1510.00	5.37	
1985	06/08/85	1830.00	5.80	3
	05/07/85	899.00	4.80	
	05/28/85	1130.00	5.03	
	06/15/85	1270.00	5.25	
1986	06/06/86	1590.00	5.42	3
	05/04/86	1110.00	4.91	
	05/26/86	1270.00	5.11	
	06/14/86	1080.00	4.84	
1987	06/09/87	1150.00	5.18	1
	05/17/87	1020.00	4.97	
1988	06/06/88	764.00	4.47	0
1989	05/10/89	644.00	4.27	0
1990	06/05/90	938.00	4.66	0
1991	05/20/91	794.00	4.59	0
1992	05/20/92	866.00	4.63	0
1993	06/16/93	1490.00	5.23	1
	05/31/93	1430.00	5.15	
1994	06/03/94	980.00	4.90	0

ND OF PROGRAM J980.

GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING WRC GUIDELINES BULL. 17-B.

XECUTION BEGINNING AT DATE, TIME = 5/18/95 1030

NPUT FORMAT = 1 WATSTORE PEAK FILE RETRIEVAL

EXPLANATION OF PEAK DISCHARGE QUALIFICATION CODES

J407 FILE [illegible]ANING

```
 D       3    DAM FAILURE, NON-RECURRENT FLOW ANOMALY
 G       8    DISCHARGE GREATER THAN STATED VALUE
 X      3+8   BOTH OF THE ABOVE
 L       4    DISCHARGE LESS THAN STATED VALUE
 K    6 OR C  KNOWN EFFECT OF REGULATION OR URBANIZATION
 H       7    HISTORIC PEAK


EPORT TROUBLE TO WATSTORE USER ASSISTANCE.




       J407 -- REVISED FOR USE WITH W.R.C. BULLETIN 17-B.   8/1/81

    PEAK FLOW FILE RETRIEVAL VERSION

    PRINCIPAL CHANGES INCLUDE --
    -- HIGH OUTLIER TEST
    -- MORE SENSITIVE LOW OUTLIER TEST
    -- STATION SKEW ADJUSTMENT FOR LOW OUTLIERS AND ZERO FLOWS
    -- WEIGHTED AVERAGING OF STATION AND GENERALIZED SKEWS IN
         INVERSE PROPORTION TO ESTIMATED MEAN SQUARE ERRORS.

    FOR DETAILS, SEE WATSTORE USER'S GUIDE, VOL.4, CH.I (1981
    REVISION), SEC.C.

    NO CHANGES IN JOB INPUT PREPARATION ARE REQUIRED IN RETRIEVAL MODE
    MINOR CHANGES MAY BE REQUIRED IN STANDALONE (CARD INPUT) MODE.

 NOTE -- IN STANDALONE MODE (CARD INPUT), A NEW FORMAT IS USED FOR
    HISTORIC AND OUTLIER INFORMATION.  SEE WATSTORE USER'S GUIDE,
    VOL.4, CH.I, SEC.C.2.K (1981 REVISION).  NO CHANGE IS NEEDED
    FOR STATIONS HAVING NO HISTORIC/OUTLIER INFORMATION.

 NOTE -- IN STANDALONE MODE, USE REGION=140K ON THE EXEC CARD.


NOTE --  SUMMARY OUTPUT IS PRODUCED BY DEFAULT, UNLESS SUPPRESSED BY
    THE  NOBC  OPTION.  (BCPU IS THE DEFAULT OPTION.)  BCPU OUTPUT

    ORDINARILY GOES TO A TEMPORARY DATA SET NAMED &&BCCARDS, WHICH IS
    AVAILABLE TO LATER STEPS OF THE JOB IN WHICH IT WAS CREATED, BUT
    IS DELETED AT THE END OF THE JOB.  TO GET A PERMANENT ONLINE DATA
    SET, TYPE BCU=ONLINE,BCDS='USERID.DATA.SET.NAME'  ON THE EXEC
    CARD FOR PKWRCA.  TO GET ACTUAL PUNCHED CARDS, TYPE BCOUT=SYSOUT
    INSTEAD.  SEE WATSTORE USER'S GUIDE VOL.4, CH.I, SEC. C.2.G & H.


 NOTE -- OLD J407 PROGRAM IS STILL AVAILABLE FOR TESTS AND COMPARISONS
    TO USE IT, TYPE PROG=J407A ON THE EXEC CARD.



GM J407 VER 3.7                            U. S. GEOLOGICAL SURVEY
REV  11/5/81)                      ANNUAL  PEAK  FLOW  FREQUENCY  ANALYSIS         -FOR GEORGE AUSTIGUY
                                    FOLLOWING WRC GUIDELINES BULL. 17-B.              RUN-DATE  5/18/95 AT 1030   SEQ  1.0001

OPTIONS IN EFFECT --    PLOT  BCPU  LGPT  NODB  PPOS  NORS  EXPR  CLIM

 STATION -  09165000      /USGS    DOLORES RIVER BELOW RICO, CO.                        1952-1994                 09165000      /USGS
```

I N P U T   D A T A   S U M M A R Y

-- YEARS OF RECORD -- SYSTEMATIC	HISTORIC	HISTORIC PEAKS	GENERALIZED SKEW	STD. ERROR OF GENERAL. SKEW	SKEW OPTION	GAGE BASE DISCHARGE	USER-SET OUTLIER CRITERIA HIGH OUTLIER	LOW OUTLIER
43	0	0	-0.114	--	WRC WEIGHTED	0.0	--	--

********* NOTICE -- PRELIMINARY MACHINE COMPUTATIONS. *********
********* USER RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION. *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.   0.0
WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED.   1   375.4
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.   3095.9

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE DISCHARGE	FLOOD BASE EXCEEDANCE PROBABILITY	LOGARITHMIC MEAN	LOGARITHMIC STANDARD DEVIATION	LOGARITHMIC SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.0632	0.1803	-0.929
W R C ESTIMATE	375.4	0.9767	3.0730	0.1556	-0.096

ANNUAL FREQUENCY CURVE ORDINATES -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	W R C ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR W R C ESTIMATES LOWER	UPPER
0.9950	--	278.8	--	--	--
0.9900	--	336.1	--	--	--
0.9500	650.0	533.4	635.6	551.8	735.7
0.9000	744.9	663.2	732.5	647.1	831.5
0.8000	876.7	841.6	869.5	779.9	966.0
0.5000	1190.0	1232.4	1190.0	1086.2	1304.1
0.2000	1602.1	1648.7	1614.5	1453.7	1801.6
0.1000	1865.5	1858.2	1894.1	1672.4	2145.0
0.0400	2189.1	2064.7	2243.9	1930.5	2586.2
0.0200	2424.2	2185.6	2514.0	2112.7	2917.7
0.0100	2654.8	2284.8	2780.0	2288.1	3250.6
0.0050	2882.9	2367.0	3062.4	2458.8	3586.8
0.0020	3182.9	2455.5	3402.5	2679.7	4038.1

GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
FOLLOWING WRC GUIDELINES BULL. 17-B.

-FOR GEORGE AUSTIGUY
RUN-DATE 5/18/95 AT 1030   SEQ 1.0001

STATION - 09165000   /USGS   DOLORES RIVER BELOW RICO, CO.   1952-1994   09165000   /USGS

********* NOTICE -- PRELIMINARY MACHINE COMPUTATIONS. *********
********* USER RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION. *********

INPUT DATA LISTING

WATER YEAR	DISCHARGE	CODES
1952	2120.0	
1953	1460.0	

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	W R C ESTIMATE
1984	2170.0	0.0227	0.0227
1952	2120.0	0.0455	0.0455

1954	786.0	1957	2080.0	0.0682	0.0682
1955	1360.0	1970	1930.0	0.0909	0.0909
1956	1020.0	1958	1900.0	0.1136	0.1136
1957	2080.0	1985	1830.0	0.1364	0.1364
1958	1900.0	1973	1810.0	0.1591	0.1591
1959	585.0	1980	1770.0	0.1818	0.1818
1960	1170.0	1975	1620.0	0.2045	0.2045
1961	1020.0	1982	1610.0	0.2273	0.2273
1962	1190.0	1979	1600.0	0.2500	0.2500
1963	867.0	1983	1590.0	0.2727	0.2727
1964	1220.0	1986	1590.0	0.2955	0.2955
1965	1330.0	1993	1490.0	0.3182	0.3182
1966	951.0	1953	1460.0	0.3409	0.3409
1967	769.0	1955	1360.0	0.3636	0.3636
1968	1360.0	1968	1360.0	0.3864	0.3864
1969	1210.0	1965	1330.0	0.4091	0.4091
1970	1930.0	1978	1330.0	0.4318	0.4318
1971	1100.0	1964	1220.0	0.4545	0.4545
1972	776.0	1969	1210.0	0.4773	0.4773
1973	1810.0	1962	1190.0	0.5000	0.5000
1974	783.0	1960	1170.0	0.5227	0.5227
1975	1620.0	1987	1150.0	0.5455	0.5455
1976	958.0	1971	1100.0	0.5682	0.5682
1977	270.0	1956	1020.0	0.5909	0.5909
1978	1330.0	1961	1020.0	0.6136	0.6136
1979	1600.0	1994	980.0	0.6364	0.6364
1980	1770.0	1976	958.0	0.6591	0.6591
1981	878.0	1966	951.0	0.6818	0.6818
1982	1610.0	1990	938.0	0.7045	0.7045
1983	1590.0	1981	878.0	0.7273	0.7273
1984	2170.0	1963	867.0	0.7500	0.7500
1985	1830.0	1992	866.0	0.7727	0.7727
1986	1590.0	1991	794.0	0.7955	0.7955

-- CONTINUED --

STATION - 09165000 /USGS DOLORES RIVER BELOW RICO, CO. 1952-1994 09165000 /USGS

********* NOTICE -- PRELIMINARY MACHINE COMPUTATIONS. *********
********* USER RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION. *********

INPUT DATA LISTING — EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

-- CONTINUED --

WATER YEAR	DISCHARGE	CODES	WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	W R C ESTIMATE
1987	1150.0		1954	786.0	0.8182	0.8182
1988	764.0		1974	783.0	0.8409	0.8409
1989	644.0		1972	776.0	0.8636	0.8636
1990	938.0		1967	769.0	0.8864	0.8864
1991	794.0		1988	764.0	0.9091	0.9091
1992	866.0		1989	644.0	0.9318	0.9318
1993	1490.0		1959	585.0	0.9545	0.9545
1994	980.0		1977	270.0	0.9773	0.9773

GM J407 VER 3.7
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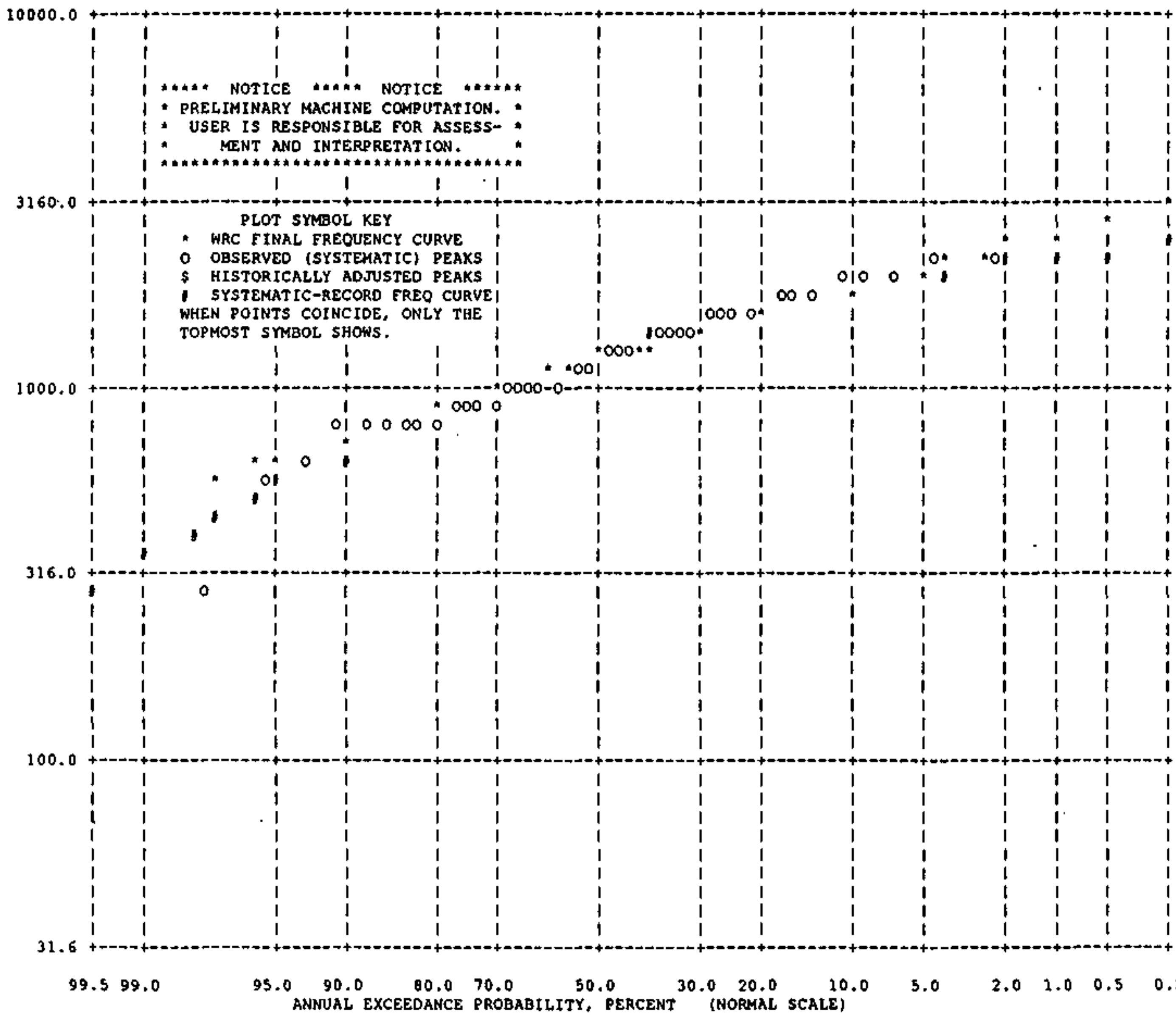
U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS -FOR GEORGE AUSTIGUY

STATION - 09165000 /USGS DOLORES RIVER BELOW RICO, CO. 1952-1994 09165000 /USGS



GM J407 VER 3.7
REV 11/5/81)

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS -FOR GEORGE AUSTIGUY

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ND JOB J407[illegible]TA.PROC, N.ERRS., N.SKIPS, STA.YEARS =        1        0     [illegible]     43
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Attachment C1B-3
HEC-2 Analysis 500 Year Flood

SOURCE FILE: DOL500.WQ2
6/20/95
ADJUSTED WATER LEVELS FOR THE 500 YR DISCHARGE ON THE DOLORES RIVER
DELTA = -5.5 FT

		WITHOUT DIKE							WITH DIKE					
		ADJ	VLOB	VCH	VROB	FROUDE			ADJ					DIFFERENCE
STA	CWSEL	CWSEL					STA	CWSEL	CWSEL	VLOB	VCH	VROB	FROUDE	
0	8311.39	8305.89	0	10.03	2.18	0.92	0	8311.39	8305.89	0	10.03	2.18	0.92	0
93	8430.14	8424.64	0	11.36	2.63	0.9	93	8430.14	8424.64	0	11.36	2.63	0.9	0
3409	8474.33	8468.83	0	12.01	7.77	0.87	3409	8474.33	8468.83	0	12.01	7.77	0.87	0
7747	8530.34	8524.84	2.46	11.08	0	0.89	7747	8530.34	8524.84	2.46	11.08	0	0.89	0
10434	8595.3	8589.8	0	8.79	2.69	0.84	10434	8595.3	8589.8	0	8.79	2.69	0.84	0
13791	8608.27	8602.77	0	5.2	1.15	0.34	13791	8608.27	8602.77	0	5.2	1.15	0.34	0
17326	8651.15	8645.65	1.19	11.55	0	0.98	17326	8651.15	8645.65	1.19	11.55	0	0.98	0
17925	8657.04	8651.54	0	5.98	1.42	0.49	17925	8657.04	8651.54	0	5.98	1.42	0.49	0
18313	8661.79	8656.29	0	9.44	4.7	1.15	18313	8661.79	8656.29	0	9.44	4.7	1.15	0
18813	8669.11	8663.61	0	8.17	0	0.75	18813	8669.11	8663.61	0	8.17	0	0.75	0
19313	8675.08	8669.58	3.28	10.98	4.21	0.88	19313	8675.08	8669.58	3.28	10.98	4.21	0.88	0
19763	8680.84	8675.34	4.25	10.93	0	0.86	19763	8680.84	8675.34	4.25	10.93	0	0.86	0
20313	8687.02	8681.52	2.83	5.64	1.37	0.59	20313	8687.02	8681.52	2.83	5.64	1.37	0.59	0
20813	8693.27	8687.77	0	6.86	0	1.06	20813	8693.18	8687.68	0	7.39	0	1.09	-0.09
21313	8700.65	8695.15	1.07	5.75	0.83	0.65	21313	8700.67	8695.17	1.07	5.71	0.83	0.65	0.02
21813	8707.93	8702.43	1.14	9.55	3.61	0.94	21813	8707.93	8702.43	1.14	9.55	3.61	0.94	0
22158	8713	8707.5	0	10.26	1.58	0.87	22158	8713	8707.5	0	10.26	1.58	0.87	0
22161	8712.7	8707.2	0	11.52	0	1	22161	8712.7	8707.2	0	11.52	0	1	0
22163	8713.26	8707.76	0	10.37	2.75	0.89	22163	8713.26	8707.76	0	10.37	2.75	0.89	0
22189	8714.9	8709.4	0	7.69	4.18	0.68	22189	8714.9	8709.4	0	7.69	4.18	0.68	0
22191	8714.81	8709.31	0	7.47	0	0.55	22191	8714.81	8709.31	0	7.47	0	0.55	0
22203	8715.13	8709.63	0	6.59	1.53	0.51	22203	8715.13	8709.63	0	6.59	1.53	0.51	0
22313	8715.75	8710.25	2.45	6.67	2.15	0.67	22313	8715.75	8710.25	2.45	6.67	2.15	0.67	0
22813	8721.07	8715.57	3.03	8.39	2.62	0.78	22813	8721.07	8715.57	3.03	8.39	2.62	0.78	0
23313	8727.04	8721.54	0	9.17	4.85	0.86	23313	8727.04	8721.54	0	9.17	4.85	0.86	0
23813	8734.28	8728.78	0	11.77	0.34	1.01	23813	8734.28	8728.78	0	11.77	0.34	1.01	0
24211	8740.65	8735.15	1.2	6.13	1.33	0.64	24211	8740.65	8735.15	1.2	6.13	1.33	0.64	0
24243	8740.98	8735.48	0	9.53	1.81	0.99	24243	8740.98	8735.48	0	9.53	1.81	0.99	0
24761	8747.72	8742.22	0	7.69	2.11	0.66	24761	8747.72	8742.22	0	7.69	2.11	0.66	0
25313	8753.83	8748.33	3.54	9	0	0.91	25313	8753.83	8748.33	3.54	9	0	0.91	0
25538	8756.77	8751.27	0	13.03	0	1.04	25538	8756.77	8751.27	0	13.03	0	1.04	0
25585	8758.3	8752.8	0	9.88	0	0.72	25585	8758.3	8752.8	0	9.88	0	0.72	0
25563	8758.4	8752.9	0	9.71	0	0.71	25563	8758.4	8752.9	0	9.71	0	0.71	0
25603	8758.98	8753.48	0	8.8	0	0.62	25603	8758.98	8753.48	0	8.8	0	0.62	0

SOURCE FILE: DOL500.WQ2
6/20/95
ADJUSTED WATER LEVELS FOR THE 500 YR DISCHARGE ON THE DOLORES RIVER
DELTA = -5.5 FT

WITHOUT DIKE							WITH DIKE							
STA	CWSEL	ADJ CWSEL	VLOB	VCH	VROB	FROUDE	STA	CWSEL	ADJ CWSEL	VLOB	VCH	VROB	FROUDE	DIFFERENCE
25608	8759.03	8753.53	0	8.76	0	0.62	25608	8759.03	8753.53	0	8.76	0	0.62	0
25633	8758.99	8753.49	0	9.79	1.38	0.75	25633	8758.99	8753.49	0	9.79	1.38	0.75	0
25813	8761.13	8755.63	0	5.83	0.46	0.5	25813	8761.13	8755.63	0	5.83	0.46	0.5	0
26313	8767.11	8761.61	2.42	8.88	3.41	0.79	26313	8767.11	8761.61	2.42	8.88	3.41	0.79	0
26813	8773.91	8768.41	0.83	10.9	2.14	0.99	26813	8773.91	8768.41	0.83	10.9	2.14	0.99	0
27313	8782.62	8777.12	0	7.83	0	0.84	27313	8782.62	8777.12	0	7.83	0	0.84	0
27843	8791.7	8786.2	0	12.13	0	1.01	27843	8791.7	8786.2	0	12.13	0	1.01	0
27868	8793.99	8788.49	0	4.77	0	0.27	27868	8793.99	8788.49	0	4.77	0	0.27	0
28313	8798.43	8792.93	0	10.8	0	1.01	28313	8798.43	8792.93	0	10.8	0	1.01	0
28813	8806.65	8801.15	0	8.45	0	0.81	28813	8806.65	8801.15	0	8.45	0	0.81	0
29313	8814.75	8809.25	0	8.76	0	1	29313	8814.75	8809.25	0	8.76	0	1	0
29813	8824.2	8818.7	0	7.75	0	0.89	29813	8824.2	8818.7	0	7.75	0	0.89	0
30313	8834.85	8829.35	0	10.9	5.57	1.07	30313	8834.85	8829.35	0	10.9	5.57	1.07	0
30813	8844.87	8839.37	0	11.28	0	1.01	30813	8844.87	8839.37	0	11.28	0	1.01	0

HEC2 S/N: 1363000398   HMVersion: 6.52   Data File: DOLRS500.HC2

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**********************************************                   ****************************************
*  HEC-2 WATER SURFACE PROFILES              *                   *  U.S. ARMY CORPS OF ENGINEERS        *
*                                            *                   *  HYDROLOGIC ENGINEERING CENTER       *
*  Version   4.6.2;  May 1991                *                   *  609 SECOND STREET, SUITE D          *
*                                            *                   *  DAVIS, CALIFORNIA 95616-4687        *
*  RUN DATE    20JUN95    TIME    9:35:00    *                   *         (916) 756-1104               *
**********************************************                   ****************************************
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X     X  XXXXXXX   XXXXX             XXXXX
X     X  X        X     X           X     X
X     X  X        X                       X
XXXXXXX  XXXX     X          XXXXX   XXXXX
X     X  X        X                 X
X     X  X        X     X           X
X     X  XXXXXXX   XXXXX            XXXXXXX
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::::::::::::::::::::::::::::::::::::::::::::::
::::::::::::::::::::::::::::::::::::::::::::::
:::                                        :::
:::   FULL MICRO-COMPUTER IMPLEMENTATION   :::
:::                                        :::
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H A E S T A D   M E T H O D S
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37 Brookside Road * Waterbury, Connecticut 06708 * (203) 755-1666

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****************************************
HEC-2 WATER SURFACE PROFILES

Version  4.6.2;  May 1991
****************************************


  DAMES & MOORE (JAN. 1981)
  REPRODUCED BY ESA (JUNE 1995)
T1  ANACONDA RICO PROJECT, FLOODPLAIN STUDY
T2  ONE HUNDRED YEAR RETURN FLOW
T3  DOLORES 500YR  (3400)

J1  ICHECK    INQ      NINV     IDIR     STRT     METRIC   HVINS    Q        WSEL     FQ

     0.0       2.0      0.0      0.0     1.26      0.0      0.0     0.0    8311.5

J2  NPROF     IPLOT    PRFVS    XSECV    XSECH    FN       ALLDC    IBW      CHNIM    ITRACE

    0.0       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0


J3  VARIABLE CODES FOR SUMMARY PRINTOUT

  150.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
    38         1         2        42        55        26        56        68

NC     0.068     0.068     0.043     0.150     0.200       0.0       0.0       0.0       0.0
QT       1.0    3400.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
X1       0.0      12.0     136.0     228.0       0.0       0.0       0.0       0.0       0.0       0.0
GR    8329.8       0.0    8317.7      34.0    8318.7      42.0    8318.4      93.0    8312.0     136.0
GR    8307.0     161.0    8305.9     179.0    8307.2     208.0    8310.5     228.0    8310.1     238.0
GR    8313.6     400.0    8317.8     462.0       0.0       0.0       0.0       0.0       0.0       0.0

X1      93.0      12.0      88.0     149.0      93.0      93.0      93.0       0.0       0.0       0.0
GR    8471.0       0.0    8431.8      88.0    8424.2      98.0    8423.1     110.0    8424.4     126.0
GR    8428.4     149.0    8429.1     169.0    8431.9     250.0    8438.8     411.0    8436.0     445.0
GR    8434.5     472.0    8462.3     516.0       0.0       0.0       0.0       0.0       0.0       0.0

X1    3409.0       7.0      40.0      71.0    3316.0    3316.0    3316.0       0.0       0.0       0.0
GR    8480.8       0.0    8475.6      12.0    8475.5      40.0    8465.3      57.0    8468.6      71.0
GR    8468.2      98.0    8508.2     126.6       0.0       0.0       0.0       0.0       0.0       0.0

X1    7747.0      12.0     127.0     193.0    4338.0    4338.0    4338.0       0.0       0.0       0.0
GR    8550.4       0.0    8533.6      39.0    8543.2      53.0    8536.8     115.0    8527.9     127.0
GR    8524.8     148.0    8524.0     166.0    8524.7     181.0    8532.1     193.0    8530.9     215.0
GR    8537.2     231.0    8539.9     245.0       0.0       0.0       0.0       0.0       0.0       0.0
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X1	10434	9.0	70.0	173.0	2687.0	2687.0	2687.0	0.0	0.0	0.0
GR	8616.2	0.0	8598.4	33.0	8597.9	70.0	8591.2	107.0	8591.0	140.0
GR	8591.1	163.0	8596.0	173.0	8593.0	488.0	8630.4	551.0	0.0	0.0
X1	13791	10.0	174.0	264.0	3357.0	3357.0	3357.0	0.0	0.0	0.0
GR	8627.9	0.0	8609.1	27.0	8611.1	174.0	8601.2	191.0	8599.7	217.0
GR	8598.7	233.0	8599.7	245.0	8605.4	264.0	8608.8	428.0	8623.3	457.0
X1	17326	11.0	160.0	234.0	3535.0	3535.0	3535.0	0.0	0.0	0.0
GR	8683.2	0.0	8669.0	34.0	8667.0	62.0	8652.8	91.0	8650.6	160.0
GR	8647.7	166.0	8646.0	188.0	8645.8	219.0	8654.5	234.0	8653.8	267.0
GR	8689.2	320.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	17925	11.0	143.0	265.0	599.0	599.0	599.0	0.0	0.0	0.0
GR	8671.8	0.0	8671.9	50.0	8658.5	75.0	8657.7	143.0	8654.0	155.0
GR	8651.0	220.0	8649.5	237.0	8650.7	253.0	8659.1	265.0	8654.7	281.0
GR	8684.3	327.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	18313	11.0	0.0	177.0	388.0	388.0	388.0	0.0	0.0	0.0
GR	8688.8	0.0	8659.0	45.0	8656.3	57.0	8657.8	75.0	8658.6	85.0
GR	8660.7	129.0	8663.1	177.0	8658.2	284.0	8665.4	300.0	8665.4	312.0
GR	8699.9	515.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	18813	11.0	0.0	163.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8684.4	0.0	8676.6	27.0	8663.8	58.0	8662.6	71.0	8663.8	88.0
GR	8666.3	98.0	8666.4	156.0	8672.1	163.0	8670.5	173.0	8673.6	428.0
GR	8705.5	479.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	19313	14.0	299.0	351.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8696.1	0.0	8676.3	221.0	8672.0	299.0	8670.5	306.0	8669.5	330.0
GR	8670.3	348.0	8673.0	351.0	8672.4	382.0	8676.7	393.0	8676.4	403.0
GR	8680.3	549.0	8677.9	559.0	8679.3	633.0	8697.3	680.0	0.0	0.0
X1	19763	13.0	222.0	340.0	450.0	450.0	450.0	0.0	0.0	0.0
GR	8693.7	0.0	8683.3	14.0	8676.2	108.0	8682.4	138.0	8683.5	176.0
GR	8684.5	222.0	8672.9	232.0	8673.9	240.0	8675.2	259.0	8683.4	274.0
GR	8683.9	322.0	8688.8	340.0	8702.7	712.0	0.0	0.0	0.0	0.0
X1	20313	19.0	297.0	463.0	550.0	550.0	550.0	0.0	0.0	0.0
GR	8723.3	0.0	8689.1	95.0	8683.1	297.0	8681.7	305.0	8683.1	312.0
GR	8685.8	333.0	8683.7	356.0	8686.1	369.0	8682.8	444.0	8682.5	450.0
GR	8682.6	457.0	8686.9	463.0	8685.8	496.0	8698.7	529.0	8701.8	609.0
GR	8695.4	617.0	8695.4	657.0	8704.9	679.0	8703.2	733.0	0.0	0.0
X1	20813	19.0	73.0	603.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	00.0	0.0	0.0	263.0	0.0					
GR	8721.9	0.0	8694.0	73.0	8692.5	346.0	8691.3	367.0	8693.1	389.0
GR	8693.1	417.0	8690.2	451.0	8687.6	461.0	8690.1	469.0	8693.6	471.0
GR	8690.4	527.0	8689.6	563.0	8690.2	576.0	8699.0	603.0	8694.8	611.0
GR	8695.6	641.0	8699.7	649.0	8703.8	745.0	8729.8	809.0	0.0	0.0

X1	21313	17.0	571.0	815.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	0.0	0.0	0.0	327.0	0.0					
GR	8730.8	0.0	8711.9	47.0	8710.9	109.0	8707.2	127.0	8701.3	467.0
GR	8699.9	571.0	8697.0	571.0	8695.5	583.0	8696.9	597.0	8699.5	637.0
GR	8697.4	751.0	8700.1	815.0	8705.1	827.0	8704.6	841.0	8701.1	857.0
GR	8707.1	1187.0	8743.5	1237.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	21813	13.0	507.0	607.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8731.7	0.0	8717.5	287.0	8707.4	507.0	8704.1	521.0	8703.8	567.0
GR	8705.2	593.0	8707.7	607.0	8705.1	657.0	8711.4	671.0	8711.1	727.0
GR	8707.8	747.0	8711.2	987.0	8761.7	1082.0	0.0	0.0	0.0	0.0
X1	22158	11.0	247.0	339.0	345.0	345.0	345.0	0.0	0.0	0.0
GR	8722.4	0.0	8719.7	209.0	8719.7	247.0	8707.5	277.0	8704.9	290.0
GR	8707.5	305.0	8712.8	339.0	8712.1	385.0	8714.2	497.0	8719.1	509.0
GR	8731.2	1077.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	22161	14.0	247.0	339.0	3.0	3.0	3.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8714.0	0.0
GR	8722.4	0.0	8719.7	209.0	8719.7	247.0	8715.0	260.0	8713.0	265.0
GR	8707.5	277.0	8704.9	290.0	8707.5	305.0	8713.0	339.0	8712.5	359.0
GR	8712.1	385.0	8714.2	497.0	8719.1	509.0	8731.2	1077.0	0.0	0.0
X1	22163	0.0	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0
BT	8.0	260.0	8715.0	8715.0	265.0	8715.0	8713.0	277.0	8715.0	8713.0
BT	290.0	8715.0	8713.0	305.0	8715.0	8713.0	339.0	8715.0	8713.0	359.0
BT	8715.0	8712.5	385.0	8712.1	8712.0	0.0	0.0	0.0	0.0	0.0
X1	22189	0.0	0.0	0.0	26.0	26.0	26.0	0.0	0.0	0.0
X2	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
X1	22191	0.0	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8715.0	0.0
X1	22203	14.0	218.0	328.0	12.0	12.0	12.0	0.0	0.0	0.0
GR	8735.0	0.0	8728.8	161.0	8728.8	173.0	8727.2	218.0	8713.9	236.0
GR	8707.7	277.0	8706.7	291.0	8707.8	308.0	8717.3	328.0	8719.4	350.0
GR	8717.1	384.0	8712.8	398.0	8720.7	808.0	8737.2	968.0	0.0	0.0
X1	22313	11.0	42.0	186.0	110.0	110.0	110.0	0.0	0.0	0.0
GR	8740.6	0.0	8712.2	42.0	8716.3	102.0	8709.9	143.0	8708.7	161.0
GR	8710.1	175.0	8714.7	186.0	8713.7	193.0	8714.8	286.0	8717.4	576.0
GR	8754.5	724.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	22813	17.0	322.0	404.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8780.4	0.0	8739.1	101.0	8722.6	236.0	8719.1	248.0	8719.9	322.0
GR	8716.8	328.0	8715.6	344.0	8716.8	369.0	8719.7	390.0	8719.7	404.0
GR	8720.1	450.0	8717.2	462.0	8719.5	470.0	8725.5	1004.0	8732.3	1043.0
GR	8730.3	1073.0	8755.0	1089.0	0.0	0.0	0.0	0.0	0.0	0.0

X1	23313	16.0	131.0	220.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8747.6	0.0	8734.2	131.0	8724.0	161.0	8722.7	181.0	8723.1	215.0
GR	8726.8	220.0	8729.3	245.0	8723.8	252.0	8724.5	262.0	8724.8	286.0
GR	8723.1	322.0	8729.4	360.0	8729.4	372.0	8735.0	402.0	8731.8	509.0
GR	8763.9	553.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	23813	10.0	0.0	88.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8752.7	0.0	8729.7	24.0	8728.9	24.0	8727.7	39.0	8728.9	55.0
GR	8729.7	55.0	8732.7	84.0	8734.2	88.0	8737.2	265.0	8752.4	400.0
X1	24211	7.0	111.0	304.0	398.0	398.0	398.0	0.0	0.0	0.0
GR	8781.2	0.0	8739.6	111.0	8737.3	251.0	8736.0	253.0	8735.5	297.0
GR	8739.5	304.0	8756.8	497.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	24243	7.0	50.0	243.0	32.0	32.0	32.0	0.0	0.0	0.0
GR	8766.3	0.0	8744.9	50.0	8736.5	200.0	8736.9	239.0	8740.4	243.0
GR	8740.4	250.0	8757.3	475.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	24761	8.0	0.0	99.0	518.0	518.0	518.0	0.0	0.0	0.0
GR	8760.0	0.0	8742.7	27.0	8743.1	87.0	8745.3	88.0	8746.4	99.0
GR	8746.6	372.0	8747.2	449.0	8764.5	659.0	0.0	0.0	0.0	0.0
X1	25313	13.0	250.0	356.0	552.0	552.0	552.0	0.0	0.0	0.0
GR	8793.0	0.0	8766.6	52.0	8752.1	115.0	8752.6	250.0	8750.9	251.0
GR	8750.3	307.0	8751.5	344.0	8758.3	356.0	8755.6	497.0	8761.7	523.0
GR	8763.8	555.0	8763.3	568.0	8770.1	586.0	0.0	0.0	0.0	0.0
X1	25538	16.0	182.0	239.0	135.0	135.0	135.0	0	0.0	0.0
GR	8777.8	0.0	8761.5	31.0	8764.5	51.0	8764.0	65.0	8758.1	80.0
GR	8757.1	182.0	8751.1	194.0	8749.6	209.0	8750.9	224.0	8758.3	239.0
GR	8763.4	261.0	8764.4	266.0	8764.7	346.0	8758.8	393.0	8760.4	423.0
GR	8782.2	444.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	25585	5.0	0.0	86.0	20.0	20.0	20.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	8769.2	8769.2	0.0
GR	8766.3	0.0	8751.1	25.0	8751.1	43.0	8751.1	61.0	8766.3	86.0
X1	25563	0.0	0.0	0.0	5.0	5.0	5.0	0.0	0.0	0.0
BT	5.0	0.0	8770.6	8766.3	25.0	8770.6	8766.8	43.0	8770.6	8767.8
BT	61.0	8770.6	8766.8	86.0	8770.6	8766.3	0.0	0.0	0.0	0.0
X1	25603	0.0	0.0	0.0	40.0	40.0	40.0	0.0	0.0	0.0
X2	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
X1	25608	0.0	0.0	0.0	5.0	5.0	5.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	8770.6	8770.6	0.0
X1	25633	9.0	102.0	186.0	25.0	25.0	25.0	0.0	0.0	0.0
GR	8768.5	0.0	8767.8	102.0	8753.2	135.0	8751.3	159.0	8752.0	172.0
GR	8759.2	186.0	8759.9	197.0	8757.9	301.0	8775.5	366.0	0.0	0.0

X1	25813	10.0	102.0	282.0	180.0	180.0	180.0	0.0	0.0	0.0
GR	8785.2	0.0	8764.8	32.0	8770.2	72.0	8769.8	102.0	8757.1	166.0
GR	8755.7	225.0	8756.2	269.0	8760.8	282.0	8761.1	300.0	8782.0	337.0
X1	26313	14.0	283.0	343.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8788.7	0.0	8768.1	43.0	8764.9	283.0	8762.1	314.0	8762.5	333.0
GR	8765.2	343.0	8767.5	397.0	8765.1	403.0	8764.9	498.0	8771.9	511.0
GR	8772.0	518.0	8780.0	532.0	8780.5	544.0	8793.8	563.0	0.0	0.0
X1	26813	10.0	300.0	382.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8777.3	0.0	8773.6	300.0	8770.1	302.0	8768.8	339.0	8772.4	382.0
GR	8777.4	390.0	8776.2	398.0	8774.4	402.0	8774.3	560.0	8783.6	574.0
X1	27313	10.0	25.0	215.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8802.7	0.0	8785.7	25.0	8777.5	83.0	8780.0	99.0	8780.5	167.0
GR	8778.4	183.0	8779.7	199.0	8786.0	215.0	8786.1	225.0	8793.8	565.0
X1	27843	13.0	0.0	86.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8803.4	0.0	8792.0	9.0	8786.4	19.0	8785.5	36.0	8786.1	53.0
GR	8790.7	70.0	8799.2	86.0	8800.0	103.0	8803.2	106.0	8788.9	162.0
GR	8794.4	216.0	8790.4	236.0	8810.2	464.0	0.0	0.0	0.0	0.0
X1	27868	7.0	72.0	162.0	25.0	25.0	25.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8800.1	0.0	8799.4	72.0	8782.9	91.0	8781.0	112.0	8783.5	138.0
GR	8799.2	162.0	8799.2	166.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	28313	12.0	0.0	120.0	445.0	445.0	445.0	0.0	0.0	0.0
X3	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8810.3	0.0	8795.7	19.0	8793.2	63.0	8796.7	101.0	8807.5	120.0
GR	8807.7	134.0	8801.3	145.0	8803.3	275.0	8809.3	290.0	8802.3	302.0
GR	8807.7	638.0	8823.9	670.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	28813	10.0	205.0	334.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8830.7	0.0	8813.1	98.0	8806.8	205.0	8803.3	209.0	8803.0	319.0
GR	8812.1	334.0	8812.0	350.0	8811.3	352.0	8811.3	526.0	8824.5	552.0
X1	29313	11.0	234.0	409.0	500.0	500.0	500.0	0.0	0.0	0.0
X3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	8827.6	0.0	8818.4	134.0	8818.7	234.0	8813.9	237.0	8811.2	292.0
GR	8813.3	398.0	8819.2	409.0	8819.3	429.0	8816.0	435.0	8815.1	655.0
GR	8827.3	685.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

X1	29813	7.0	21.0	321.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8839.3	0.0	8826.9	21.0	8820.8	234.0	8820.5	298.0	8835.6	321.0
GR	8832.5	340.0	8845.6	360.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	30313	7.0	0.0	71.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8870.7	0.0	8830.7	28.0	8830.9	33.0	8832.4	71.0	8832.8	212.0
GR	8839.2	223.0	8842.6	287.0	0.0	0.0	0.0	0.0	0.0	0.0
X1	30813	10.0	75.0	176.0	500.0	500.0	500.0	0.0	0.0	0.0
GR	8857.5	0.0	8846.0	15.0	8845.6	75.0	8841.7	81.0	8839.8	108.0
GR	8841.1	146.0	8855.7	176.0	8848.4	193.0	8848.7	214.0	8855.7	259.0

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    SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
    Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
    TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
    SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

*PROF 1

CCHV=    0.150 CEHV=     0.200
*SECNO 0.000
3720 CRITICAL DEPTH ASSUMED
     0.000      5.49   8311.39   8311.39   8311.50   8312.91      1.51      0.00      0.00   8312.00
    3400.0       0.0    3292.2     107.8       0.0     328.3      49.5       0.0       0.0   8310.50
      0.00      0.00     10.03      2.18     0.000     0.043     0.068     0.000   8305.90    139.05
  0.014932        0.        0.        0.         0         5         0      0.00    158.71    297.76


*SECNO 93.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    93.000      7.04   8430.14   8430.14      0.00   8432.08      1.94      1.33      0.09   8431.80
    3400.0       0.0    3286.2     113.8       0.0     289.2      43.3       0.8       0.3   8428.40
      0.00      0.00     11.36      2.63     0.000     0.043     0.068     0.000   8423.10     90.19
  0.013649       93.       93.       93.        20        11         0      0.00    108.83    199.02


*SECNO 3409.000
  3409.000      9.03   8474.33      0.00      0.00   8476.05      1.72     43.94      0.03   8475.50
    3400.0       0.0    2053.6    1346.4       0.0     171.1     173.3      26.5       6.7   8468.60
      0.09      0.00     12.01      7.77     0.000     0.043     0.068     0.000   8465.30     41.96
  0.012869     3316.     3316.     3316.         6         0         0      0.00     60.41    102.38


*SECNO 7747.000
  7747.000      6.34   8530.34      0.00      0.00   8532.24      1.90     56.15      0.04   8527.90
    3400.0       9.8    3390.2       0.0       4.0     306.0       0.0      59.1      13.0   8532.10
      0.20      2.46     11.08      0.00     0.068     0.043     0.000     0.000   8524.00    123.72
  0.013020     4338.     4338.     4338.         5         0         0      0.00     66.42    190.14


*SECNO 10434.000

3265 DIVIDED FLOW


3301 HV CHANGED MORE THAN HVINS
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
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 SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
 Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
 TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
 SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 10434.000      4.30   8595.30   8595.30      0.00   8596.25      0.96     34.51      0.14   8597.90
    3400.0       0.0    2641.2     758.8       0.0     300.6     281.7      86.6      25.3   8596.00
      0.30      0.00      8.79      2.69     0.000     0.043     0.068     0.000   8591.00     84.37
  0.012670     2687.     2687.     2687.        20        20         0      0.00    332.34    491.87

*SECNO 13791.000

3301 HV CHANGED MORE THAN HVINS


3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  2.72

 13791.000      9.57   8608.27      0.00      0.00   8608.66      0.39     12.32      0.08   8611.10
    3400.0       0.0    3170.2     229.8       0.0     609.2     199.2     140.2      46.8   8605.40
      0.49      0.00      5.20      1.15     0.000     0.043     0.068     0.000   8598.70    178.85
  0.001718     3357.     3357.     3357.         5         0         0      0.00    223.80    402.65

*SECNO 17326.000

3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 17326.000      5.35   8651.15   8651.15      0.00   8653.22      2.07     13.91      0.33   8650.60
    3400.0       5.6    3394.4       0.0       4.7     294.0       0.0     185.1      59.3   8654.50
      0.58      1.19     11.55      0.00     0.068     0.043     0.000     0.000   8645.80    142.76
  0.016595     3535.     3535.     3535.        20        11         0      0.00     85.47    228.22

*SECNO 17925.000

3265 DIVIDED FLOW


3301 HV CHANGED MORE THAN HVINS
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  SECNO       DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q           QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME        VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE       XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  2.10

 17925.000      7.54   8657.04       0.00       0.00    8657.59       0.55       4.15       0.23    8657.70
    3400.0       0.0    3379.9       20.1        0.0      565.2       14.2      191.2       60.8    8659.10
      0.60      0.00      5.98       1.42      0.000      0.043      0.068      0.000    8649.50     145.14
  0.003774      599.      599.       599.          4          0          0       0.00     129.05     284.63

*SECNO 18313.000

3265 DIVIDED FLOW


3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 18313.000      5.49   8661.79    8661.79       0.00    8662.95       1.16       2.91       0.12    8688.80
    3400.0       0.0    2670.1      729.9        0.0      282.9      155.1      195.7       62.2    8663.10
      0.62      0.00      9.44       4.70      0.000      0.043      0.068      0.000    8656.30      40.79
  0.021505      388.      388.       388.         20         19          0       0.00     196.44     291.98

*SECNO 18813.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.45

 18813.000      6.51   8669.11       0.00       0.00    8670.14       1.04       7.17       0.02    8684.40
    3400.0       0.0    3400.0        0.0        0.0      416.1        0.0      200.6       64.0    8672.10
      0.63      0.00      8.17       0.00      0.000      0.043      0.000      0.000    8662.60      45.15
  0.010248      500.      500.       500.          5          0          0       0.00     114.17     159.32

*SECNO 19313.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 19313.000      5.58   8675.08    8675.08       0.00    8676.64       1.57       5.68       0.11    8672.00
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3400.0	281.8	2768.6	349.5	86.0	252.2	82.9	205.4	65.5	8673.00
0.65	3.28	10.98	4.21	0.068	0.043	0.068	0.000	8669.50	243.14
0.012678	500.	500.	500.	3	12	0	0.00	145.71	388.85

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 19763.000

3265 DIVIDED FLOW

19763.000	7.94	8680.84	0.00	0.00	8682.31	1.47	5.66	0.01	8684.50
3400.0	828.1	2571.9	0.0	194.7	235.3	0.0	209.8	66.9	8688.80
0.66	4.25	10.93	0.00	0.068	0.043	0.000	0.000	8672.90	46.56
0.012461	450.	450.	450.	1	0	0	0.00	128.06	269.32

*SECNO 20313.000

3301 HV CHANGED MORE THAN HVINS

20313.000	5.32	8687.02	0.00	0.00	8687.43	0.41	4.96	0.16	8683.10
3400.0	731.9	2635.1	33.0	258.8	467.0	24.0	217.3	69.9	8686.90
0.69	2.83	5.64	1.37	0.068	0.043	0.068	0.000	8681.70	165.00
0.006830	550.	550.	550.	4	0	0	0.00	334.13	499.12

*SECNO 20813.000

3265 DIVIDED FLOW

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

20813.000	5.67	8693.27	8693.27	0.00	8694.00	0.73	6.07	0.06	8694.00
3400.0	0.0	3400.0	0.0	0.0	495.6	0.0	224.4	73.9	8699.00
0.71	0.00	6.86	0.00	0.000	0.043	0.000	0.000	8687.60	206.12
0.027338	500.	500.	500.	8	8	0	0.00	373.31	585.41

*SECNO 21313.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, XRATIO = 1.77

21313.000	5.15	8700.65	0.00	0.00	8701.16	0.51	7.13	0.03	8699.90
3400.0	22.7	3376.9	0.3	21.3	587.2	0.4	230.7	77.8	8700.10
0.74	1.07	5.75	0.83	0.068	0.043	0.068	0.000	8695.50	514.75
0.008737	500.	500.	500.	6	0	0	0.00	301.58	816.34

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SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

*SECNO 21813.000

3265 DIVIDED FLOW


3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 21813.000     4.13   8707.93   8707.93     0.00   8709.23     1.31      5.80      0.16   8707.40
    3400.0      3.4    3086.7     309.9      3.0     323.1     85.8     236.6      80.5   8707.70
      0.75     1.14      9.55      3.61    0.068     0.043    0.068     0.000   8703.80    495.56
  0.016137     500.      500.      500.        4        15        0      0.00    177.38    755.89


*SECNO 22158.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 22158.000     8.10   8713.00   8713.00     0.00   8714.60     1.60      4.99      0.06   8719.70
    3400.0      0.0    3326.3      73.7      0.0     324.3     46.7     239.7      81.9   8712.80
      0.76     0.00     10.26      1.58    0.000     0.043    0.068     0.000   8704.90    263.48
  0.013054     345.      345.      345.        2        17        0      0.00    169.42    432.90


*SECNO 22161.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=     8719.70 ELREA=      8714.00

 22161.000     7.80   8712.70   8712.70     0.00   8714.76     2.06      0.05      0.09   8719.70
    3400.0      0.0    3400.0       0.0      0.0     295.0      0.0     239.7      81.9   8713.00
      0.76     0.00     11.52      0.00    0.000     0.043    0.000     0.000   8704.90    265.66
  0.017439       3.        3.        3.        3         8        0      0.00     71.48    337.14


*SECNO 22163.000

3370 NORMAL BRIDGE, NRD=   8 MIN ELTRD=  8712.10 MAX ELLC=  8715.00

 22163.000     8.36   8713.26   8712.85     0.00   8714.88     1.62      0.05      0.07   8719.70
    3400.0      0.0    3287.0     113.0      0.0     316.9     41.1     239.7      81.9   8713.00
      0.76     0.00     10.37      2.75    0.000     0.043    0.068     0.000   8704.90    264.38
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0.033268	2.	2.	2.	15	12	0	-47.14	181.85	446.23

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SECNO     DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    L-BANK ELEV
Q         QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA      R-BANK ELEV
TIME      VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN    SSTA
SLOPE     XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID   ENDST

*SECNO 22189.000

3301 HV CHANGED MORE THAN HVINS

3370 NORMAL BRIDGE, NRD=   8 MIN ELTRD=  8712.10 MAX ELLC=  8715.00

 22189.000    10.00  8714.90     0.00     0.00  8715.63     0.74     0.63     0.13  8719.70
    3400.0      0.0   2437.8    962.2      0.0    316.9    230.3    240.0     82.0  8713.00
      0.76     0.00     7.69     4.18    0.000    0.043    0.068    0.000  8704.90   260.28
  0.018299      26.      26.      26.        3        0        0  -219.54   238.41   498.69

*SECNO 22191.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.98

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=     8719.70 ELREA=     8715.00

 22191.000     9.91  8714.81     0.00     0.00  8715.68     0.87     0.02     0.03  8719.70
    3400.0      0.0   3400.0      0.0      0.0    454.9      0.0    240.0     82.1  8713.00
      0.76     0.00     7.47     0.00    0.000    0.043    0.000    0.000  8704.90   260.48
  0.004685       2.       2.       2.        2        0        0     0.00    78.52   339.00

*SECNO 22203.000

3265 DIVIDED FLOW

 22203.000     8.43  8715.13     0.00     0.00  8715.76     0.63     0.05     0.04  8727.20
    3400.0      0.0   3169.0    231.0      0.0    480.9    151.0    240.2     82.1  8717.30
      0.76     0.00     6.59     1.53    0.000    0.043    0.068    0.000  8706.70   234.32
  0.003991      12.      12.      12.        2        0        0     0.00   218.18   519.43

*SECNO 22313.000

3265 DIVIDED FLOW

 22313.000     7.05  8715.75     0.00     0.00  8716.36     0.61     0.59     0.00  8712.20
    3400.0     22.7   2949.6    427.7      9.3    442.5    198.9    241.8     82.8  8714.70
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0.77	2.45	6.67	2.15	0.068	0.043	0.068	0.000	8708.70	36.76
0.007553	110.	110.	110.	2	0	0	0.00	342.46	390.98

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 22813.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

22813.000	5.47	8721.07	8721.07	0.00	8721.89	0.83	4.50	0.04	8719.90
3400.0	372.1	2468.3	559.6	122.7	294.3	214.0	249.2	86.9	8719.70
0.79	3.03	8.39	2.62	0.068	0.043	0.068	0.000	8715.60	241.25
0.010902	500.	500.	500.	5	14	0	0.00	368.33	609.58

*SECNO 23313.000

3265 DIVIDED FLOW

23313.000	4.34	8727.04	0.00	0.00	8728.01	0.97	6.09	0.03	8734.20
3400.0	0.0	2183.8	1216.2	0.0	238.1	250.6	255.6	90.0	8726.80
0.81	0.00	9.17	4.85	0.000	0.043	0.068	0.000	8722.70	152.08
0.013679	500.	500.	500.	3	0	0	0.00	168.09	345.72

*SECNO 23813.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

23813.000	6.58	8734.28	8734.28	0.00	8736.43	2.15	7.90	0.24	8752.70
3400.0	0.0	3399.9	0.1	0.0	288.8	0.2	260.1	91.3	8734.20
0.82	0.00	11.77	0.34	0.000	0.043	0.068	0.000	8727.70	19.22
0.018463	500.	500.	500.	2	14	0	0.00	73.33	92.55

*SECNO 24211.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.54

24211.000	5.15	8740.65	0.00	0.00	8741.23	0.58	4.57	0.24	8739.60
3400.0	1.8	3388.5	9.7	1.5	552.8	7.3	263.9	92.6	8739.50
0.84	1.20	6.13	1.33	0.068	0.043	0.068	0.000	8735.50	108.21
0.007812	398.	398.	398.	4	0	0	0.00	208.57	316.78

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 24243.000

3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

24243.000	4.48	8740.98	8740.98	0.00	8742.39	1.40	0.37	0.16	8744.90
3400.0	0.0	3388.5	11.5	0.0	355.7	6.3	264.3	92.8	8740.40
0.84	0.00	9.53	1.81	0.000	0.043	0.068	0.000	8736.50	119.96
0.018736	32.	32.	32.	20	11	0	0.00	137.79	257.75

*SECNO 24761.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.56

24761.000	5.02	8747.72	0.00	0.00	8748.43	0.71	5.94	0.10	8760.00
3400.0	0.0	2559.9	840.1	0.0	333.1	398.4	270.8	96.2	8746.40
0.86	0.00	7.69	2.11	0.000	0.043	0.068	0.000	8742.70	19.16
0.007727	518.	518.	518.	5	0	0	0.00	436.17	455.33

*SECNO 25313.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

25313.000	3.53	8753.83	8753.83	0.00	8754.86	1.03	5.92	0.06	8752.60
3400.0	732.5	2667.5	0.0	206.6	296.4	0.0	278.6	100.5	8758.30
0.88	3.54	9.00	0.00	0.068	0.043	0.000	0.000	8750.30	107.47
0.015877	552.	552.	552.	3	19	0	0.00	240.64	348.12

*SECNO 25538.000

3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

25538.000	7.17	8756.77	8756.77	0.00	8759.40	2.64	2.30	0.32	8757.10
3400.0	0.0	3400.0	0.0	0.0	261.0	0.0	279.8	100.9	8758.30
0.88	0.00	13.03	0.00	0.000	0.043	0.000	0.000	8749.60	182.67
0.018278	135.	135.	135.	20	17	0	0.00	53.23	235.89

```
SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

*SECNO 25585.000

3301 HV CHANGED MORE THAN HVINS


3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.46


3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      8769.20 ELREA=      8769.20

 25585.000      7.20   8758.30      0.00      0.00   8759.81      1.51      0.24      0.17   8766.30
    3400.0       0.0    3400.0       0.0       0.0     344.2       0.0     279.9     100.9   8766.30
      0.88      0.00      9.88      0.00     0.000     0.043     0.000     0.000   8751.10     13.16
  0.008613       20.       20.       20.         6         0         0      0.00     59.67     72.84

*SECNO 25563.000

3370 NORMAL BRIDGE, NRD=    5 MIN ELTRD=  8770.60 MAX ELLC=  8767.80

 25563.000      7.30   8758.40      0.00      0.00   8759.86      1.46      0.04      0.01   8766.30
    3400.0       0.0    3400.0       0.0       0.0     350.2       0.0     280.0     101.0   8766.30
      0.88      0.00      9.71      0.00     0.000     0.043     0.000     0.000   8751.10     13.00
  0.008199        5.        5.        5.         2         0         0      0.00     60.00     73.00

*SECNO 25603.000

3370 NORMAL BRIDGE, NRD=    5 MIN ELTRD=  8770.60 MAX ELLC=  8767.80

 25603.000      7.88   8758.98      0.00      0.00   8760.18      1.20      0.28      0.04   8766.30
    3400.0       0.0    3400.0       0.0       0.0     386.4       0.0     280.3     101.0   8766.30
      0.88      0.00      8.80      0.00     0.000     0.043     0.000     0.000   8751.10     12.02
  0.006189       40.       40.       40.         2         0         0      0.00     61.95     73.98

*SECNO 25608.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      8770.60 ELREA=      8770.60

 25608.000      7.93   8759.03      0.00      0.00   8760.22      1.19      0.03      0.00   8766.30
    3400.0       0.0    3400.0       0.0       0.0     388.2       0.0     280.3     101.0   8766.30
```

0.88	0.00	8.76	0.00	0.000	0.043	0.000	0.000	8751.10	11.98
0.006107	5.	5.	5.	0	0	0	0.00	62.05	74.02

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 25633.000

3265 DIVIDED FLOW

25633.000	7.69	8758.99	8757.87	0.00	8760.46	1.47	0.18	0.06	8767.80
3400.0	0.0	3354.2	45.8	0.0	342.6	33.1	280.6	101.1	8759.20
0.89	0.00	9.79	1.38	0.000	0.043	0.068	0.000	8751.30	121.91
0.009055	25.	25.	25.	4	15	0	0.00	124.38	305.03

*SECNO 25813.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.48

25813.000	5.43	8761.13	0.00	0.00	8761.66	0.53	1.06	0.14	8769.80
3400.0	0.0	3398.4	1.6	0.0	583.2	3.4	282.6	101.6	8760.80
0.89	0.00	5.83	0.46	0.000	0.043	0.068	0.000	8755.70	145.65
0.004144	180.	180.	180.	2	0	0	0.00	154.42	300.07

*SECNO 26313.000

3265 DIVIDED FLOW

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

26313.000	5.01	8767.11	8767.11	0.00	8767.92	0.81	3.15	0.06	8764.90
3400.0	443.5	2094.2	862.3	183.2	235.9	252.9	289.8	104.7	8765.20
0.91	2.42	8.88	3.41	0.068	0.043	0.068	0.000	8762.10	117.21
0.010745	500.	500.	500.	20	10	0	0.00	374.77	502.10

*SECNO 26813.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

26813.000	5.11	8773.91	8773.91	0.00	8775.75	1.84	6.74	0.21	8773.60
3400.0	3.2	3392.9	3.9	3.8	311.3	1.8	295.5	107.5	8772.40
0.93	0.83	10.90	2.14	0.068	0.043	0.068	0.000	8768.80	275.06
0.017409	500.	500.	500.	3	9	0	0.00	109.35	384.41

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 27313.000

3301 HV CHANGED MORE THAN HVINS

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8785.70 ELREA= 8786.00

27313.000	5.12	8782.62	0.00	0.00	8783.57	0.95	7.69	0.13	8785.70
3400.0	0.0	3400.0	0.0	0.0	434.0	0.0	299.8	109.0	8786.00
0.95	0.00	7.83	0.00	0.000	0.043	0.000	0.000	8777.50	46.81
0.013686	500.	500.	500.	2	0	0	0.00	159.60	206.41

*SECNO 27843.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8803.40 ELREA= 8799.20

27843.000	6.20	8791.70	8791.70	0.00	8793.99	2.29	7.70	0.27	8803.40
3400.0	0.0	3400.0	0.0	0.0	280.2	0.0	303.9	110.3	8799.20
0.96	0.00	12.13	0.00	0.000	0.043	0.000	0.000	8785.50	9.54
0.017440	500.	500.	500.	3	11	0	0.00	62.35	71.88

*SECNO 27868.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 4.01

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8799.40 ELREA= 8799.20

27868.000	12.99	8793.99	0.00	0.00	8794.35	0.35	0.07	0.29	8799.40
3400.0	0.0	3400.0	0.0	0.0	713.2	0.0	304.1	110.3	8799.20
0.96	0.00	4.77	0.00	0.000	0.043	0.000	0.000	8781.00	78.23
0.001086	25.	25.	25.	3	0	0	0.00	75.81	154.04

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 28313.000

3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8810.30 ELREA= 8807.50

28313.000	5.23	8798.43	8798.43	0.00	8800.24	1.81	1.25	0.29	8810.30
3400.0	0.0	3400.0	0.0	0.0	314.8	0.0	309.4	111.2	8807.50
0.97	0.00	10.80	0.00	0.000	0.043	0.000	0.000	8793.20	15.45
0.018453	445.	445.	445.	20	18	0	0.00	88.59	104.04

*SECNO 28813.000

3301 HV CHANGED MORE THAN HVINS

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8806.80 ELREA= 8812.10

28813.000	3.65	8806.65	0.00	0.00	8807.76	1.11	7.41	0.11	8806.80
3400.0	0.0	3400.0	0.0	0.0	402.6	0.0	313.5	112.4	8812.10
0.99	0.00	8.45	0.00	0.000	0.043	0.000	0.000	8803.00	205.17
0.012175	500.	500.	500.	4	0	0	0.00	119.85	325.02

*SECNO 29313.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 8818.70 ELREA= 8819.20

29313.000	3.55	8814.75	8814.75	0.00	8815.94	1.19	7.78	0.02	8818.70
3400.0	0.0	3400.0	0.0	0.0	388.2	0.0	318.1	114.0	8819.20
1.00	0.00	8.76	0.00	0.000	0.043	0.000	0.000	8811.20	236.47
0.020557	500.	500.	500.	4	8	0	0.00	164.23	400.70

*SECNO 29813.000

29813.000	3.70	8824.20	0.00	0.00	8825.13	0.93	9.15	0.04	8826.90
3400.0	0.0	3400.0	0.0	0.0	438.8	0.0	322.8	116.0	8835.60
1.02	0.00	7.75	0.00	0.000	0.043	0.000	0.000	8820.50	115.41
0.016399	500.	500.	500.	4	0	0	0.00	188.22	303.63

```
 SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
 Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
 TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
 SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


*SECNO 30313.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 30313.000       4.15    8834.85    8834.85       0.00    8835.98       1.13       9.49       0.04    8870.70
    3400.0        0.0     1612.1     1787.9        0.0      147.9      321.1      328.0      118.2    8832.40
      1.04       0.00      10.90       5.57      0.000      0.043      0.068      0.000    8830.70      25.09
  0.022233       500.       500.       500.          3          8          0       0.00     190.43     215.53


*SECNO 30813.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
 30813.000       5.07    8844.87    8844.87       0.00    8846.84       1.98       9.98       0.17    8845.60
    3400.0        0.0     3400.0        0.0        0.0      301.4        0.0      332.4      119.7    8855.70
      1.05       0.00      11.28       0.00      0.000      0.043      0.000      0.000    8839.80      76.13
  0.018027       500.       500.       500.          4         11          0       0.00      77.62     153.74
```

THIS RUN EXECUTED 20JUN95 9:35:03

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HEC-2 WATER SURFACE PROFILES

Version 4.6.2; May 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

RES 500YR (3400)

SUMMARY PRINTOUT

	SECNO	CWSEL	CRIWS	ELMIN	VLOB	VCH	VROB	FRCH
*	0.000	8311.39	8311.39	8305.90	0.00	10.03	2.18	0.92
*	93.000	8430.14	8430.14	8423.10	0.00	11.36	2.63	0.90
	3409.000	8474.33	0.00	8465.30	0.00	12.01	7.77	0.87
	7747.000	8530.34	0.00	8524.00	2.46	11.08	0.00	0.89
*	10434.000	8595.30	8595.30	8591.00	0.00	8.79	2.69	0.84
*	13791.000	8608.27	0.00	8598.70	0.00	5.20	1.15	0.34
*	17326.000	8651.15	8651.15	8645.80	1.19	11.55	0.00	0.98
*	17925.000	8657.04	0.00	8649.50	0.00	5.98	1.42	0.49
*	18313.000	8661.79	8661.79	8656.30	0.00	9.44	4.70	1.15
*	18813.000	8669.11	0.00	8662.60	0.00	8.17	0.00	0.75
*	19313.000	8675.08	8675.08	8669.50	3.28	10.98	4.21	0.88
	19763.000	8680.84	0.00	8672.90	4.25	10.93	0.00	0.86
	20313.000	8687.02	0.00	8681.70	2.83	5.64	1.37	0.59
*	20813.000	8693.27	8693.27	8687.60	0.00	6.86	0.00	1.06
*	21313.000	8700.65	0.00	8695.50	1.07	5.75	0.83	0.65
*	21813.000	8707.93	8707.93	8703.80	1.14	9.55	3.61	0.94
*	22158.000	8713.00	8713.00	8704.90	0.00	10.26	1.58	0.87

	SECNO	CWSEL	CRIWS	ELMIN	VLOB	VCH	VROB	FRCH
*	22161.000	8712.70	8712.70	8704.90	0.00	11.52	0.00	1.00
	22163.000	8713.26	8712.85	8704.90	0.00	10.37	2.75	0.89
	22189.000	8714.90	0.00	8704.90	0.00	7.69	4.18	0.68
*	22191.000	8714.81	0.00	8704.90	0.00	7.47	0.00	0.55
	22203.000	8715.13	0.00	8706.70	0.00	6.59	1.53	0.51
	22313.000	8715.75	0.00	8708.70	2.45	6.67	2.15	0.67
*	22813.000	8721.07	8721.07	8715.60	3.03	8.39	2.62	0.78
	23313.000	8727.04	0.00	8722.70	0.00	9.17	4.85	0.86
*	23813.000	8734.28	8734.28	8727.70	0.00	11.77	0.34	1.01
*	24211.000	8740.65	0.00	8735.50	1.20	6.13	1.33	0.64
*	24243.000	8740.98	8740.98	8736.50	0.00	9.53	1.81	0.99
*	24761.000	8747.72	0.00	8742.70	0.00	7.69	2.11	0.66
*	25313.000	8753.83	8753.83	8750.30	3.54	9.00	0.00	0.91
*	25538.000	8756.77	8756.77	8749.60	0.00	13.03	0.00	1.04
*	25585.000	8758.30	0.00	8751.10	0.00	9.88	0.00	0.72
	25563.000	8758.40	0.00	8751.10	0.00	9.71	0.00	0.71
	25603.000	8758.98	0.00	8751.10	0.00	8.80	0.00	0.62
	25608.000	8759.03	0.00	8751.10	0.00	8.76	0.00	0.62
	25633.000	8758.99	8757.87	8751.30	0.00	9.79	1.38	0.75
*	25813.000	8761.13	0.00	8755.70	0.00	5.83	0.46	0.50
*	26313.000	8767.11	8767.11	8762.10	2.42	8.88	3.41	0.79
*	26813.000	8773.91	8773.91	8768.80	0.83	10.90	2.14	0.99
	27313.000	8782.62	0.00	8777.50	0.00	7.83	0.00	0.84
*	27843.000	8791.70	8791.70	8785.50	0.00	12.13	0.00	1.01
*	27868.000	8793.99	0.00	8781.00	0.00	4.77	0.00	0.27
*	28313.000	8798.43	8798.43	8793.20	0.00	10.80	0.00	1.01

	SECNO	CWSEL	CRIWS	ELMIN	VLOB	VCH	VROB	FRCH
	28813.000	8806.65	0.00	8803.00	0.00	8.45	0.00	0.81
*	29313.000	8814.75	8814.75	8811.20	0.00	8.76	0.00	1.00
	29813.000	8824.20	0.00	8820.50	0.00	7.75	0.00	0.89
*	30313.000	8834.85	8834.85	8830.70	0.00	10.90	5.57	1.07
*	30813.000	8844.87	8844.87	8839.80	0.00	11.28	0.00	1.01

C2 HYDRAULIC FACILITIES

ARMY COE 1991 METHOD

FROM HEC-2

SITE	V_{avg} (ft/s)
COLUMBIA TAILS	8
SANTA CRUZ	8
SILVER SWAN	9

FOR STRAIGHT REACHES R/W > 40

$Y = 6.67$ FT

$V_{ss}/V_{av} = 0.9$ FROM PLATE B-33

$D_{30} = 0.3$ FT $= 3.6$ in

ADJUSTED FOR 1V:2H SLOPE $\Rightarrow$ $\cot\theta = 2$

FROM PLATE B-39 $C_2 = 1.2$

$D_0' = C_2 D_0 = 1.2(0.3) = 0.36$ FT $= 4.32$ in

ADJUSTED FOR 1V:3H $\cot\theta = 3$

$C_2 = 1.0$

$D' = D_0 = 0.3$ FT

FOR CURVED SECTIONS

a) COLUMBIA TAILS $R/W = \frac{600}{150} = 4$

$Y = 6.67$ FT

$V_{ss}/V_{av} = 1.44 \Rightarrow V_{ss} = 1.44(8) = 11.5$ fps

$D_{30} = 0.65$ FT $= 7.8$ in (1V:4H)

$D_{30} = 0.65$ FT $= 7.8$ in (1V:3H)

$D_{30} = 1.2(0.65) = 0.78$ FT $= 9.4$ in (1V:2H)

b) SILVER SWAN => DIKE ON INSIDE OF CURVE USE STRAIGHT REACH CALCULATIONS

GRADATION

SIMONS & SENTURK GRADATION

PERCENT FINER	PARTICLE SIZE
0	$0.25\ D_{50}$
10	$0.35\ D_{50}$
20	$0.5\ D_{50}$
30	$0.65\ D_{50}$
40	$0.8\ D_{50}$
50	$1.0\ D_{50}$
60	$1.2\ D_{50}$
70	$1.6\ D_{50}$
90	$1.8\ D_{50}$
100	$2.0\ D_{50}$

$$D_{30} = 0.65\ D_{50} \Rightarrow D_{50} = D_{30}/0.65$$

FOR STRAIGHT REACHES

$$0.3 \leq D_{30} \leq 0.36 \Rightarrow 0.46 \leq D_{50} \leq 0.55$$

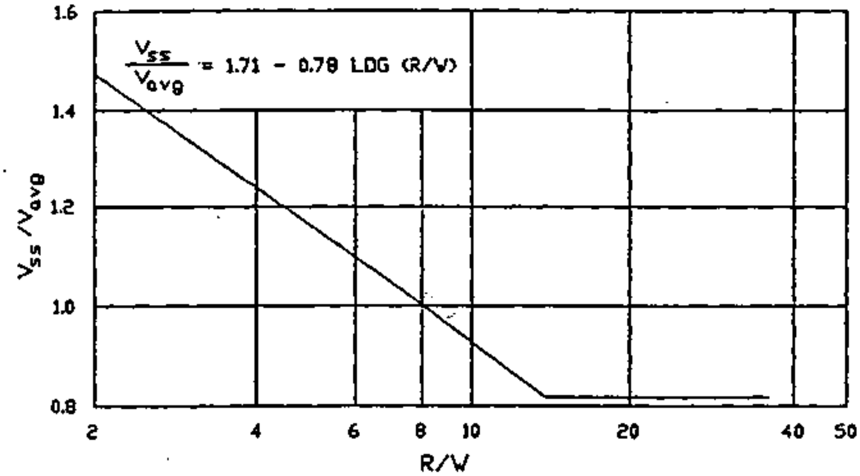
FOR COLUMBIA TAILS CURVE

$$0.65 \leq D_{30} \leq 0.78 \Rightarrow 1 \leq D_{50} \leq 1.2$$

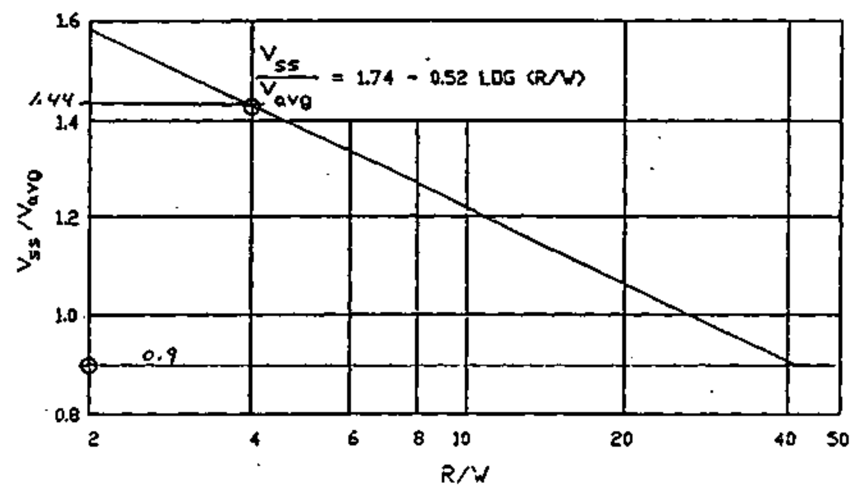
SOURCE FILE :RICORPRP.WQ2
06/21/95
RIPRAP GRADATION FOR FLOOD PROTECTION DIKES
BASED ON ARMY COE 1991 METHOD AND SIMONS AND SENTURK GRADATION

SIDE SLOPES	D30 (FT)	D50 (FT)
STRAIGHT CHANNEL 1V:2H	0.36	0.55
STRAIGHT CHANNEL 1V:3H	0.3	0.46
STRAIGHT CHANNEL 1V:4H	0.3	0.46
CURVED CHANNEL 1V:2H	0.78	1.2
CURVED CHANNEL 1V:3H	0.65	1
CURVED CHANNEL 1V:4H	0.65	1

		STRAIGHT CHANNEL SECTION			CURVED CHANNEL SECTION		
%FINER	D50 COEFF	1V:2H PARTICL SIZE (IN)	1V:3H PARTICL SIZE (IN)	1V:4H PARTICLE SIZE (IN)	1V:2H PARTIC SIZE (IN)	1V:3H PARTIC SIZE (IN)	1V:4H PARTICLE SIZE (IN)
0	0.25	1.65	1.38	1.38	3.6	3	3
10	0.35	2.31	1.932	1.932	5.04	4.2	4.2
20	0.5	3.3	2.76	2.76	7.2	6	6
30	0.65	4.29	3.588	3.588	9.36	7.8	7.8
40	0.8	5.28	4.416	4.416	11.52	9.6	9.6
50	1	6.6	5.52	5.52	14.4	12	12
60	1.2	7.92	6.624	6.624	17.28	14.4	14.4
70	1.6	10.56	8.832	8.832	23.04	19.2	19.2
90	1.8	11.88	9.936	9.936	25.92	21.6	21.6
100	2	13.2	11.04	11.04	28.8	24	24



TRAPEZOIDAL CHANNEL

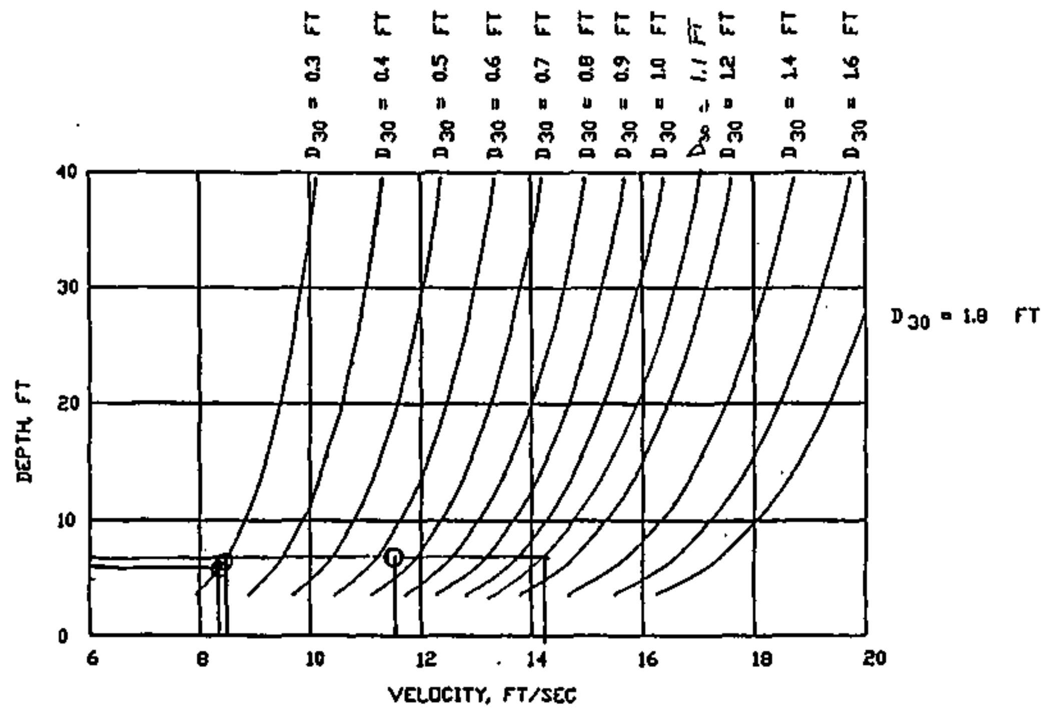


NATURAL CHANNEL

NOTE: V_{ss} IS DEPTH-AVERAGED VELOCITY AT 20 PERCENT OF SLOPE LENGTH UP FROM TOE

RIPRAP DESIGN VELOCITIES

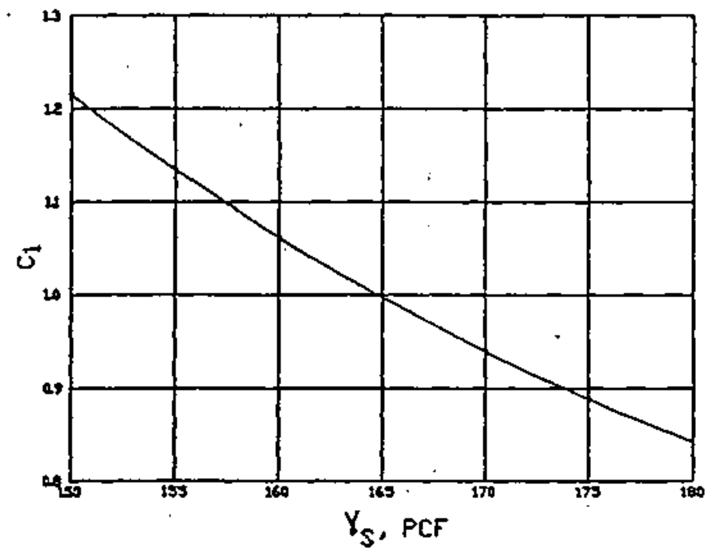
PLATE B-33



NOTE: APPLICABLE TO THICKNESS 1D$_{100}$(max) AND CHANNEL BOTTOMS OR SIDE SLOPES FLATTER THAN OR EQUAL TO 1V ON 4H. STONE WEIGHT 165 pcf, C_S = 0.30, C_V = C_T = 1.0 S_f = 1.1 BASED ON EQUATION 3-3.

DEPTH-AVERAGED VELOCITY VS D30 AND DEPTH

PLATE B-37



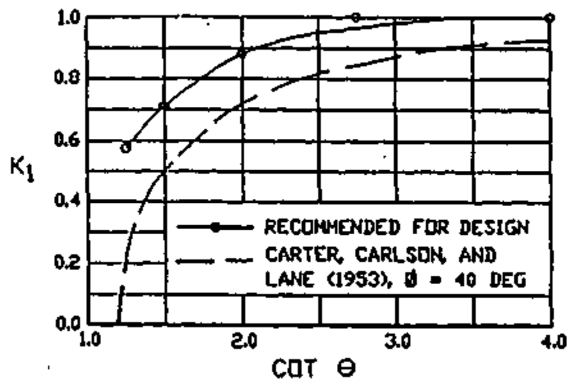
$D_{30} = C_1 * (D_{30}$ FROM PLATE 37)

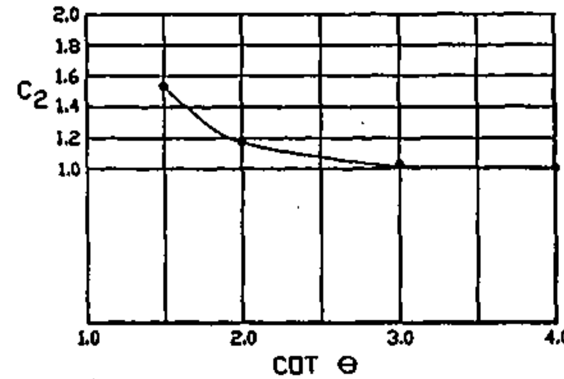
WHERE C_1 = CORRECTION FOR UNIT STONE WEIGHT

NOTE: DO NOT MAKE THIS CORRECTION IF D_{30} COMPUTED FROM EQUATION 3-3

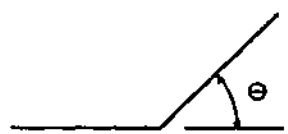
CORRECTION FOR UNIT STONE WEIGHT

PLATE B-38





K_1 = SIDE SLOPE CORRECTION COEFFICIENT FOR USE IN EQUATION 3-3 ONLY.



D_{30} = C_2*(D_{30} FROM PLATE 37)

WHERE C_2 = CORRECTION FOR SIDE SLOPE ANGLE

NOTE : DO NOT MAKE THIS CORRECTION IF D_{30} COMPUTED FROM EQUATION 3-3.

CORRECTION FOR SIDE SLOPE ANGLE

PLATE B-39

Silver Swan
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\arco\rico\silswn1.fm2
Worksheet	Pile runon channel (Basin A8)
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.035	
Channel Slope	0.030000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	10.00	ft
Discharge	28.00	ft^3/s

Results		
Depth	0.54	ft
Flow Area	6.31	ft^2
Wetted Perimeter	13.45	ft
Top Width	13.26	ft
Critical Depth	0.59	ft
Critical Slope	0.022797	ft/ft
Velocity	4.44	ft/s
Velocity Head	0.31	ft
Specific Energy	0.85	ft
Froude Number	1.13	
Flow is supercritical.		

Silver Swan
Worksheet for Triangular Channel

Project Description	
Project File	c:\arco\rico\silswn1.fm2
Worksheet	Wetlands Runon Channel (Basins A6 +A8)
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.035	
Channel Slope	0.006000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	2.00	H : V
Discharge	129.00	ft^3/s

Results		
Depth	3.16	ft
Flow Area	30.03	ft^2
Wetted Perimeter	20.12	ft
Top Width	18.98	ft
Critical Depth	2.58	ft
Critical Slope	0.017713	ft/ft
Velocity	4.30	ft/s
Velocity Head	0.29	ft
Specific Energy	3.45	ft
Froude Number	0.60	
Flow is subcritical.		

C3 WETLANDS DESIGN

Silver Swan Wetlands
Aerobic Ponds Sludge Accumulation

Average Flow (gpm)	50	
Average Iron Concentration (mg/l)	4.7	Use average of Iron-T for samples
Average iron removal (ppd)	2.82	Assume complete removal of all iron
Iron Hydroxide removed (ppd)	5.39	Assume all iron removed converted to iron hydroxide
Aerobic Cell Volume (acre-ft)	0.7	upstream cell only
Aerobic Cell Volume (cf)	30492	
Assumed Usable Percentage	80	assumes cell is functional with only 20 % of volume
Usable Storage Volume (cf)	24394	

Assumed range of percent by weight sludge of three to ten.

Minimum Weight % solids:	3
Iron Sludge Volume Generated (cf/d):	2.9
Yearly Sludge Volume produced (cf):	1051
Storage life of aerobic cell (yrs):	23
Maximum Weight % solids:	10
Iron Sludge Volume Generated (cf/d):	0.9
Yearly Sludge Volume produced (cf):	315
Storage life of aerobic cell (yrs):	77

C4 MINE WASTE VOLUME AND ASSAY DATA

THOMAS Engineering Inc.

215 NORTH LINDEN STREET CORTEZ, COLORADO 81321 PHONE: 303-565-4496

Anaconda Copper Co.
September 5, 1980

Volumes for Silver Creek, Columbia and Swan Millsite Settling Ponds near Rico, Colorado

Silver Creek (ARGENTINE MILL TAILINGS)

Pond #	Vol. including dikes	Vol. without dikes
1	266,422.54 C.Y.	156,380.68 C.Y.
2	18,184.90 C.Y.	8,037.91 C.Y.
3	45,666.17 C.Y.	15,036.70 C.Y.
4	12,338.32 C.Y.	2,175.79 C.Y.

Columbia (Tailings)

44,932.5 C.Y.

Swan (Mine Waste)

15,078.76 C.Y.

Fredric P. Thomas, PE-LS
Colo. Reg. No. 6728

FREDRIC P. THOMAS REGISTERED 6728 P.E. AND L.S. STATE OF COLORADO

ANACONDA Copper Company
Division of The ANACONDA Company
Denver, Colorado

MADE BY____ DATE____ CHECKED BY____ DATE____

Silver Creek #1

Assume porosity 40% $e = \frac{0.4}{1-0.4} = 0.67$

$\gamma_D = \frac{3.24(62.4)}{1+0.67} = 121 \text{ lbs/ft}^3$

$266,422.54 \text{ cyd} \times 27 \text{ cu ft/cyd} \times 121 \text{ lbs/ft}^3 \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 435,201 \text{ Tons}$

Silver Creek #2

$\gamma_D = \frac{2.34(62.4)}{1+0.67} = 125 \text{ lbs/ft}^3$

$18,184.90 \times 27 \times 125 \times \frac{1}{2000} = 30,687 \text{ Tons}$

Silver Creek #3

$\gamma_D = \frac{3.17(62.4)}{1.67} = 118 \text{ lbs/ft}^3$

$45,666.17 \times 27 \times 118 \times 1/2000 = 72,746 \text{ Tons}$

Silver Creek #4

$\gamma_D = \frac{3.00(62.4)}{1.67} = 112 \text{ lbs/ft}^3$

$12,338.32 \times 27 \times 112 \times 1/2000 = 18,656 \text{ Tons}$

Columbia

$\gamma_D = \frac{3.13(62.4)}{1.67} = 117 \text{ lbs/ft}^3$

$44,922.5 \times 27 \times 117 \times 1/2000 = 70,971 \text{ Tons}$

Swan Dump

$\gamma_D = \frac{2.67(62.4)}{1.67} = 101 \text{ lbs/ft}^3$

$15,078.76 \times 27 \times 101 \times 1/2000 = 20,560 \text{ Tons}$

ANACONDA Copper Company

Division of The ANACONDA Company
Denver, Colorado

MADE BY______ DATE______ CHECKED BY______ DATE______

Silver Creek

455,201 x 1.07 = 465,665.07
30,687 x 1.16 = 35,596.92
72,746 x 0.24 = 61,106.64
18,656 x 1.11 = 20,708.16

557,290. 583,077

557,000 tons @ 1.05

The Specific Gravities for each of the ponds and dumps are as follows:

ARGENTINE MILL TAILINGS	Silver Creek #1 (Highest Pond)	3.24
	Silver Creek #2	3.34
	Silver Creek #3	3.17
	Silver Creek #4 (Lowest Pond)	3.00
	Columbia Tailing	3.13
	Swan Dump	2.69

ANACONDA Copper Company Internal Correspondence

Date: October 3, 1980

To: Carla Stout

From: Phillip R. Engelhardt

Subject: Head Assays of Samples from Rico, Colorado

A total of 80 samples from Rico, Colorado were received at the Tucson research center on August 7, 1980 and given the designation 80-131-1 through 80. These included samples from the Silver Creek, Columbia and Swan properties.

These samples were dried and prepared for assaying and further test work. Composites of the samples will be made and these will be assayed for beryllium.

The attached table lists the samples by our MRD number followed by your location designation. The samples were all assayed for silver, gold, lead and zinc.

Phillip R. Engelhardt

PHILLIP R. ENGELHARDT

PRE:sm

Attachment

pc: WBDavis
BLVance
JSuttie

ASSAYS OF RICO, COLORADO SAMPLES

MRD No.	Location	No.	oz/ton Ag	oz/ton Au	% Pb	% Zn
80-131-1	Swan	201A } jam	0.46	<0.005	0.61	0.30
80-131-2	Swan	201B	0.90	<0.005	1.38	0.87
80-131-3	Swan	202 out	0.32	<0.005	0.61	0.42
80-131-4	Swan	203A	1.46	0.006	2.31	1.46
80-131-5	Swan	203B	2.58	0.010	2.14	1.86
80-131-6	Swan	204	0.38	<0.005	0.74	0.52
80-131-7	Swan	205	1.32	<0.005	1.81	0.89
80-131-8	Swan	206	0.78	<0.005	1.46	0.75
80-131-9	Swan	207 out	0.16	<0.005	0.64	0.38
80-131-10	Swan	208	0.54	<0.005	1.25	0.47
80-131-11	Swan	209	2.28	<0.005	1.08	0.81
80-131-12	Swan	210 } jam	0.44	<0.005	1.39	0.53
80-131-13	Swan	210A	0.98	<0.005	1.93	1.56
80-131-14	Swan	211	0.84	0.006	0.52	0.69
80-131-15	Swan	211B don't count	1.84	0.005	4.83	1.96
80-131-16	Swan	212A	0.98	~~1.09~~ 0.109	2.22	0.97
80-131-17	Swan	212B	0.62	0.015	0.69	0.55
80-131-18	Swan	213	0.84	<0.005	1.72	0.54
80-131-19	Swan	214	1.93	0.007	1.72	0.94
80-131-20	Swan	215	0.85	0.006	0.92	0.50
80-131-21	Swan	216	0.96	<0.005	2.56	0.53
80-131-22	Swan	217	0.98	<0.005	2.31	0.73
80-131-23	Swan	218	1.09	<0.005	1.72	0.33
80-131-24	Swan	219	5.17	0.006	0.74	0.47
80-131-25	Swan	220	0.11	<0.005	<0.01	0.01
80-131-26	Columbia	101	0.94	0.006	0.71	2.32
80-131-27	Columbia	102-9 1/2	1.52	0.010	0.88	1.27
80-131-28	Columbia	102-17	1.52	0.006	0.84	1.08
80-131-29	Columbia	103-14	0.84	0.006	0.83	0.90
80-131-30	Columbia	105-14	0.64	0.006	0.61	0.77
80-131-31	Columbia	106-17	0.76	0.008	0.61	1.84
80-131-32	Columbia	107-11	0.92	0.006	0.98	1.08
80-131-33	Columbia	108-11 1/2	0.70	0.010	0.92	0.83
80-131-34	Columbia	109-10	0.66	0.006	1.01	1.11
80-131-35	Columbia	110-10	1.04	0.008	0.77	2.35
80-131-36	Columbia	111-11 1/2	0.78	0.006	0.73	1.85
80-131-37	Columbia	112-14 1/2	0.60	0.010	0.44	0.55
80-131-38	Columbia	113-10	0.70	0.006	0.81	0.69
80-131-39	Columbia	114-10	0.96	0.010	0.61	1.31
80-131-40	Columbia	115-55	0.60	0.010	0.61	1.31
80-131-41	Columbia	117-10	0.60	0.006	0.78	0.87
80-131-42	Silver Creek	2-E	0.75	0.008	----	----
80-131-43	Silver Creek	2-F	1.34	0.010	1.07	1.38
80-131-44	Silver Creek	3-D	0.82	0.006	0.51	0.95
80-131-45	Silver Creek	3-E	1.40	0.008	1.11	1.13
80-131-46	Silver Creek	4-D	0.68	0.002	0.66	1.51
80-131-47	Silver Creek	4-E	1.20	0.010	0.51	0.62

ASSAYS OF RICO, COLORADO SAMPLES (continued)

MRD No.	Location No.	oz/ton Ag	oz/ton Au	% Pb	% Zn
80-131-48	Silver Creek 5-C	1.76	0.008	0.93	1.76
80-131-49	Silver Creek 5-D	1.12	0.006	0.83	1.61
80-131-50	Silver Creek 5-E	1.22	0.008	0.61	1.62
80-131-51	Silver Creek 6-B	1.44	0.006	1.42	1.82
80-131-52	Silver Creek 6-C	0.80	0.006	0.81	0.97
80-131-53	Silver Creek 6-D	1.00	0.008	0.85	1.11
80-131-54	Silver Creek 7-C	0.91	0.022	0.71	0.82
80-131-55	Silver Creek 7-D	1.16	0.008	0.80	1.07
80-131-56	Columbia 116	0.72	0.002	0.64	0.57
80-131-57	Silver Creek 8-C	1.08	<0.005	1.38	1.39
80-131-58	Silver Creek 8-E#1	0.94	<0.005	0.93	1.21
80-131-59	Silver Creek 8-E#2	0.56	<0.005	0.55	0.96
80-131-60	Silver Creek 9-B	1.16	<0.005	1.72	1.53
80-131-61	Silver Creek 11-C	0.78	<0.005	0.57	1.10
80-131-62	Silver Creek 11-D	1.16	0.006	0.63	1.09
80-131-63	Silver Creek 11-E	1.22	0.008	1.11	1.82
80-131-64	Silver Creek 2-E	1.16	0.008	1.17	1.80
80-131-65	Silver Creek 11-5C	1.02	0.006	0.95	1.36
80-131-66	Silver Creek 11-5D-5	1.12	0.006	1.13	2.34
80-131-67	Silver Creek 12-C	1.16	0.006	0.63	0.86
80-131-68	Silver Creek 12-D	0.88	<0.005	1.00	1.50
80-131-69	Silver Creek 12-E	1.76	0.008	2.32	3.27
80-131-70	Silver Creek 12-5D5	0.84	<0.005	1.10	1.27
80-131-71	Silver Creek 13-D	0.92	<0.005	1.24	1.54
80-131-72	Silver Creek 13-E	0.92	<0.005	1.11	1.86
80-131-73	Silver Creek 14-D	0.68	<0.005	0.79	2.08
80-131-74	Silver Creek 14-E	0.84	<0.005	0.86	1.69
80-131-75	Silver Creek 16-E	1.04	<0.005	1.42	1.61
80-131-76	Silver Creek 17-E	1.00	<0.005	1.61	1.81
80-131-77	Silver Creek 18-E	1.44	<0.005	2.86	2.37
80-131-78	Silver Creek 19-E	1.02	<0.005	1.63	1.44
80-131-79	Silver Creek 98	0.84	<0.005	0.81	1.12
80-131-80	Silver Creek 99	0.80	<0.005	1.01	2.69